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**TEACHER-CLASS, TEACHER-GROUP AND
STUDENT INTERACTIONS: OPPORTUNITIES
FOR LEARNING IN PRIMARY SCIENCE
CLASSROOMS**

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Dip. Tch., B. Ed. (Hons)

This thesis is presented for the degree of Doctor of Philosophy at the Faculty of
Community Services, Education and Social Science

EDITH COWAN UNIVERSITY
PERTH WESTERN AUSTRALIA

August 2001

I certify that this thesis does not, to the best of my knowledge and belief:

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A solid black rectangular box used to redact the signature of the author.

Christine Ann Coulstock

ABSTRACT

Many studies have investigated learning in science classes, examining various influences on the understandings that students develop. The purpose of this study was to investigate the interactions that took place in upper primary science lessons, and the way the teacher and student behaviours affected these interactions and the opportunities for learning.

The three classes that were selected for the study were similar and the teachers were all experienced primary teachers. The teachers were supplied with a set of science lessons on the topic of electric circuits. The resources included background information for the teachers and suggested activities, demonstrations, analogies and focus questions that the teachers could use to develop scientifically valid understandings. The student activities were designed to allow the students to investigate and solve problems related to electric circuits, and to then discuss the activities in their groups to develop understandings. Whole-class discussions were used to further develop the understandings and then the students, in their groups, used their new knowledge to solve theoretical problems.

The data collection was broad to ensure that as much information as possible was obtained. The students participated in pre and posttests, with one group of students from each class also interviewed prior to and after the series of lessons about their understandings. All the teacher interactions with the class and with groups of students were audio-recorded, and one group of students, the group that was interviewed, was video and audio-recorded. The researcher also attended all the science lessons and recorded anecdotal records of the activities during the lesson, and any blackboard work that occurred.

The data analysis examined the types of teacher and student behaviours that occurred; the quantity and types of interactions that occurred in the whole-class and group discussions; the management of the task and behaviours in whole-class and group activities; the way the lesson time was used by the teacher and by the students in their group work; the use and understanding of scientific vocabulary; and the understandings that were developed by the students. The analysis revealed important differences in the teaching behaviours of the three teachers and in the ways that they related to their students. The teachers changed the curriculum materials, sometimes purposefully, but sometimes inadvertently, resulting in changed learning opportunities for the students,

and often used scientific terms incorrectly and/or did not explain them. The teachers' management of time, student behaviour, tasks and discussions were very different and affected the flow of lessons and opportunities students had to develop understandings. The students' level of attention and responsibility for task management also varied between students and between the classes. Students' group work skills were generally found to be inadequate to manage group relationships and tasks.

Because of the scope of the data, which encompasses many variables, it was not intended nor possible to establish any direct causal relationships between particular teaching/learning variables and the learning outcomes, but it was possible to suggest links between aspects of the learning environment, opportunities for learning and changes in the students' understandings. From the data, specific assertions were generated and these were collated to produce general assertions, which were again aggregated to produce the overarching assertions, the findings of the study.

These findings are consistent with those from many previous studies of classroom interactions and behaviours. However, they also indicated that the classroom ethos; the management strategies and styles of the teachers; the teaching style of the teacher; the ways that discussions were conducted; the level of involvement, responsibility and independence of the students; and the way time was used had an impact on the learning opportunities during the lessons and the development of acceptable, scientific understandings.

This study, which provides an in-depth analysis of the complexity of the teaching-learning process in primary science lessons, offers insights which may be useful in other learning areas, as many of the findings are not specific to the science aspects of the lessons studied.

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The teachers who allowed me into their classrooms to conduct this study also deserve my heartfelt thanks -- as a teacher I am aware of the disruption that this type of activity can cause, but they and the students were helpful and willing to give up their time for interviews and tests.

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CONTENTS

ABSTRACT	iii
ACKNOWLEDGEMENTS	v
LIST OF TABLES	xiv
LIST OF FIGURES	xvii
CHAPTER 1: BACKGROUND TO THE STUDY	1
Introduction	1
Significance of this Study	3
Purpose of this Study	3
Research Questions	3
Primary Research Question	3
Secondary Research Questions	3
CHAPTER 2: LITERATURE REVIEW	5
Introduction	5
Constructivism	5
Social Constructivism	5
Social Constructivism in the Classroom	7
Origins of Alternative Frameworks	8
Conceptual Change	9
The Conditions Necessary for Conceptual Change	10
Metacognition	11
Ontological, Epistemological and Social-affective Aspects	11
Mental Models	13
Whole-Class Discussion	14
Teacher Explanations or Monologues	14
Discussions	15
Recitations and Reviews	16
Questioning	17
The Relationship between Whole-Class Discussions and Conceptual Change Learning	20
Group Work	20
Types of Group Work	21
Effects of Group Composition	21
Time on Task	22
Roles of Participants	23
Group Size and Participation	25
Interactions in Groups	25
Learning in Groups	26
The Relationship between Group Work and Conceptual Change Learning	27

CHAPTER 2:
Continued LITERATURE REVIEW

Language	28
Word Meanings in Science Lessons	29
Understanding Interactions in the Classroom	29
Language Links	30
The Relationship between Language and Conceptual Change Learning	30
Teacher Knowledge	31
Teacher Understandings	31
The Effects of Limited Teacher Knowledge on Teaching and Learning	32
The Effects of Sound Teacher Knowledge on Teaching and Learning	32
The Relationship between Teacher Knowledge and Conceptual Change Learning	33
Opportunity to Learn	33
Alternative Frameworks	34
Alternative Frameworks in Electricity	34
Teaching for Conceptual Change in Electricity	37
Summary and Conceptual Framework	38

CHAPTER 3: METHODOLOGY 42

Introduction	42
The Researcher	42
The Choice of Research Methods	43
Participant Selection	43
Selection of Schools and Teachers	43
Selection of Students for Focus Groups	44
Selection of Data Gathering Techniques	44
The Teachers and the Schools	45
Lesson and Instrument Design	46
Choice of Topic Area	46
Development of Lessons	46
Development of Instruments	47
Validity and Reliability of the Lessons and Tests	48
Trialing of Lessons, Tests and Interview Cards	48
Overview of Lessons	49
Lesson Structure	49
Lesson 1	50
Lesson 2	52
Lesson 3	53
Lesson 4	54
Lesson 5	56

CHAPTER 3: METHODOLOGY

Continued

Data Collection and Analysis	56
Testing	56
Analysis of Data from Testing	57
Video and Audio Recordings	57
Analysis of Data Contained in Transcriptions	58
Students' Written Work	59
Collation and Analysis of Data	59
Research Consistency	60
Confidentiality/Ethics	60

CHAPTER 4: OVERVIEW OF TEACHERS AND SCHOOLS INVOLVED IN THE STUDY

Introduction	61
The First School	61
Mr Avery and his Class	61
The Class	61
The Classroom Environment	62
Mr Avery	62
Science Topics and Lessons	64
Mr Avery's Approach to Teaching the Electricity Topic	64
Use of Class Time During Electricity Lessons	64
Lesson 1: Circuit Construction, Current and Current Flow	65
Lesson 2: Conductors and Insulators	65
Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages	66
Lesson 4: Parallel Circuits	66
Extra Lesson	67
The Second School	67
Ms Brown and her Class	68
The Class	68
The Classroom Environment	69
Ms Brown	69
Science Topics and Lessons	71
Ms Brown's Approach to Teaching the Electricity Topic	72
Use of Class Time During Electricity Lessons	72
Lesson 1: Circuit Construction, Current and Current Flow	72
Lesson 2: Conductors and Insulators	72
Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages	73
Lesson 4: Parallel Circuits	74

CHAPTER 4: OVERVIEW OF TEACHERS AND SCHOOLS INVOLVED
Continued IN THE STUDY

Mr Carter and his Class	74
The Class	74
The Classroom Environment	75
Mr Carter	75
Science Topics and Lessons	77
Mr Carter's Approach to Teaching the Electricity Topic	78
Use of Class Time: During Electricity Lessons	78
Lesson 1: Circuit Construction, Current and Current Flow	78
Lesson 2: Conductors and Insulators	79
Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages	79
Lesson 4: Parallel Circuits	80
Summary	81

CHAPTER 5: WHOLE-CLASS TEACHING IN THE THREE CLASSROOMS 83

Overview	83
Mr Avery	83
Classroom Management	83
Whole-class Discussions	83
Interactions and Use of Time in Lessons	84
Use and Understanding of Scientific Vocabulary	91
Ms Brown	92
Classroom Management	92
Whole-class Discussions	93
Interactions and Use of Time in Lessons	94
Use and Understanding of Scientific Vocabulary	100
Mr Carter	102
Classroom Management	102
Whole-class Discussions	103
Interactions and Use of Time in Lessons	104
Use and Understanding of Scientific Vocabulary	112

CHAPTER 5:

continued

WHOLE-CLASS TEACHING IN THE THREE CLASSROOMS

Discussion	114
The Teachers' Management of and Strategies Used During Whole-class Discussions	114
The Teachers Management of and Strategies Used During Whole-class Discussions Related to Current Activities	122
The Teachers' Management of and Strategies Used During Whole-class Discussions Related to Reviewing Work	126
The Students' Participation and Behaviours During Whole-class Discussions	129

CHAPTER 6: TEACHER INTERACTIONS WITH SMALL GROUPS AND SMALL GROUP WORK

134

Overview	134
Mr Avery	134
General	134
Interactions between Mr Avery and Groups	134
Student Participation	137
Use of Scientific Vocabulary	140
Ms Brown	140
General	140
Interactions between Ms Brown and Groups	141
Student Participation	143
Use of Scientific Vocabulary	145
Mr Carter	146
General	146
Interactions between Mr Carter and Groups	146
Student Participation	151
Use of Scientific Vocabulary	153
Discussion	153
The Teachers' Interactions with Groups	153
Student Participation when Teachers Attended Groups.	160

CHAPTER 7: INTERACTIONS WITHIN FOCUS GROUPS

163

Overview	163
Mr Avery's Class	163
The Focus Group	163
Focus Group Use of Group Work Time	164
Focus Group Work Habits	165
Pattern and Number of Interactions Within the Focus Group	167

CHAPTER 7: INTERACTIONS WITHIN FOCUS GROUPS

Continued

Types of Interactions	168
Use and Understanding of Scientific Vocabulary	169
Ms Brown's class	170
The Focus Group	170
Focus Group Use of Group Work Time	171
Focus Group Work Habits	172
Pattern and Number of Interactions Within the Focus Group	173
Types of Interactions	174
Use and Understanding of Scientific Vocabulary	178
Mr Carter's class	179
The Focus Group	179
Focus Group Use of Group Work Time	180
Focus Group Work Habits	183
Pattern and Number of Interactions Within the Focus Group	183
Types of Interactions	184
Use and Understanding of Scientific Vocabulary	186
Discussion	186

CHAPTER 8: HOW THE PROPOSITIONS WERE TAUGHT: A COMPARISON OF TEACHING METHODS

Overview	197
Mr Avery's and Ms Brown's Teaching of Proposition 5: Electric Current Travels in One Direction Through a Circuit	197
Mr Avery's Teaching	198
Changes in Students' Understandings	203
Ms Brown's Teaching	205
Changes in Students' Understandings	212
Comparison of Changes Between Classes	214
Discussion	215
Mr Avery's Teaching of Propositions 2 and 3: Concepts Relating to the Amount of Current in Parts of a Circuit and Concepts Relating to Joins in a Circuit	219
Introduction	219
Mr Avery's Teaching of Proposition 2: The Amount of Electric Current in any Part of the Circuit will be the Same.	219
Changes in Students' Understandings	224

CHAPTER 8:	Mr Avery's Teaching of Proposition 3: Joins in a Circuit Consisting of Wires, Batteries and Globes Need to be at Specific Points on the Batteries and Globes to Result in a Working Circuit.	225
<i>continued</i>	Changes in Students' Understandings	233
	Comparison of Changes Between Propositions	234
	Discussion	234
CHAPTER 9:	THE STUDENTS' DEVELOPMENT OF UNDERSTANDING	238
	Introduction	238
	Mr Avery's Class	239
	Pre and Posttest Results for the Whole Class	239
	Pre and Posttest Results for the Focus Group	240
	Whole Class Conceptual Changes between Pre and Posttests by Proposition	241
	Ms Brown's Class	250
	Pre and Posttest Results for the Whole Class	250
	Pre and Posttest Results for the Focus Group	251
	Whole Class Conceptual Changes between Pre and Posttests by Proposition	252
	Mr Carter's Class	262
	Pre and Posttest Results for the Whole Class	262
	Pre and Posttest Results for the Focus Group	263
	Whole Class Conceptual Changes between Pre and Posttests by Proposition	263
	Comparison of Classes	273
	Whole Class results	273
	Focus Group Results	275
	Discussion	276
CHAPTER 10:	SYNTHESIS OF ASSERTIONS	281
	Introduction	281
	Summary and Analysis of Assertions	281
	Summary	304
	Classroom Ethos	304
	Curriculum Use	305
	Types of Interactions	305
	Discussions and Demonstrations	305
	Group Work	307
	Summation	308

CHAPTER 11:	LIMITATIONS, CONCLUSIONS AND IMPLICATIONS	310
	Limitations	310
	Conclusions	310
	Secondary Research Questions	319
	Primary Research Question	319
	Implications	320
	Overview	320
	Implications for Teaching and Curriculum Development	320
	Implications for Research	326
	In Conclusion	327
REFERENCES		328
APPENDIX 1	Questionnaire: Teacher Background Information	339
APPENDIX 2	Semi-structured Interview Questions for Teacher Interviews	341
APPENDIX 3	Diagrams Supplied with Lesson Outlines	342
APPENDIX 4	Pre and Posttest	343
APPENDIX 5	Semi-structured Interview Questions Using Interview-About-Instance Cards	348
APPENDIX 6	Sample Answers and Scores for Pre and Posttests	350
APPENDIX 7	Sample Extracts from Transcripts	352
APPENDIX 8	List of Assertions	356

TABLES

Table	Page
5.1 Interactions Between Mr Avery and Students in Whole-class Discussions	91
5.2 Interactions Between Ms Brown and Students in Whole-class Discussions	100
5.3 Interactions Between Mr Carter and Students in Whole-class Discussions	112
6.1 Types of Interactions Between Mr Avery and Students in the Small Group Situation	139
6.2 Types of Interactions Between Ms Brown and Students in the Group Situation	145
6.3 Types of Interactions Between Mr Carter and Students in the Group Situation	152
8.1 Type and number of Student Responses to Question 9 from Mr Avery's Class on the Pre and Posttests (n = 25)	204
8.2 Type and number of Student Responses to Question 9 from Ms Brown's Class in Pre and Posttests (n = 32)	213
8.3 Changes in Students' Understanding of Circuit Flow from Pre to Posttest	214
8.4 Type and Number of Student Responses to Q 5 and Q 10 from Mr Avery's Class on the Pre and Posttest (n = 25)	224
8.5 Type and number of Student Responses to Questions 7a and 7b from Mr Avery's Class on the Pre and Posttests (n = 25)	233
8.6 Changes in Students' Understanding of Propositions 2 and 3	234
9.1 Changes Between Pre and Posttests in Student Conceptions of Flow of Electrical Current in Components not in a Circuit (n = 25)	241
9.2 Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 25)	242
9.3 Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 25)	244
9.4 Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electric Circuit (n = 25)	245
9.5 Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 25)	246
9.6 Changes Between Pre and Posttests in Student Conceptions of Materials That Will Allow the Flow of Electric Current (n = 25)	247
9.7 Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Series (n = 25)	249

Table		Page
9.8	Changes Between Pre and Posttests in Student Conceptions of the Effects Connecting Batteries in Parallel (n = 25)	250
9.9.	Changes Between Pre and Posttests in Students Conceptions of Flow of Electrical Current in Components Not in a Circuit (n = 32)	252
9.10	Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 32)	253
9.11	Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 32)	255
9.12	Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electrical Circuit (n = 32)	256
9.13	Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 32)	257
9.14	Changes Between Pre and Posttests in Student Conceptions of Materials that will Allow Electric Current to Flow Through Them (n = 32)	258
9.15	Changes Between Pre and Posttests in Student Conceptions of the Effect of Connecting Batteries in Series (n = 32)	260
9.16	Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Parallel (n = 32)	261
9.17	Changes Between Pre and Posttests in Student Conceptions of Flow of Electrical Current in Components Not in a Circuit (n = 30).	264
9.18	A Comparison of Focus Group Student Choices for Questions 1, 2 and 3 between the Posttest and Interview	265
9.19	Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 30)	266
9.20	Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 30)	267
9.21	Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electrical Circuit (n = 30)	268
9.22	Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 30)	269
9.23	Changes Between Pre and Posttests in Student Conceptions of Materials that will Allow the Flow of Electric Current (n = 30)	270
9.24	Changes Between Pre and Posttests in Student Conceptions of the Effect of Connecting Batteries in Series (n = 30)	272
9.25	Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Parallel (n = 30)	273
9.26	Percentage Increase in Scores Between Pretest and Posttest for all Classes by Proposition	274

Table		Page
9.27	Increase in Percentage Total Test Scores for Focus Group Students from Mr Avery's Class	275
9.28	Increase in Percentage Total Test Scores for Focus Group Students from Ms Brown's Class	275
9.29	Increase in Percentage Total Test Scores for Focus Group Students from Mr Carter's Class	276

FIGURES

Figure	Page
2.1 Teaching and learning for conceptual growth and change	39
2.2 Teaching and learning for conceptual growth and change: Aspects that may affect learning	40
3.1 Circuit used to demonstrate the amount of electric current in the wires	51
3.2 Format of role-play activity	51
3.3 Circuits constructed by students in Lesson 2	52
3.4 Circuit used to demonstrate current flow in series circuits	54
3.5 Circuits used in the whole-class investigation	55
5.1 Use of whole-class discussion time: Teacher utterances	85
5.2 Use of whole-class discussion time: Student utterances	87
5.3 Use of whole-class discussion time: Teacher utterances	94
5.4 Use of whole-class discussion time: Student utterances	96
5.5 Use of whole-class discussion time: Teacher utterances	105
5.6 Use of whole-class discussion time: Student utterances	108
5.7 Whole-class teaching: Opportunities for learning	122
5.8 Whole-class teaching: Opportunities for learning specific to discussion of current activities	126
5.9 Whole-class teaching: Opportunities for learning in reviews	129
5.10 Student involvement in whole-class discussion: Opportunities for learning	132
6.1 Teacher utterances by category when attending groups	135
6.2 Student utterances by category when teacher attending groups	138
6.3 Teacher utterances by category when attending groups	141
6.4 Student utterances by category when teacher attending groups	144
6.5 Teacher utterances by category when attending groups	147
6.6 Student utterances by category when teacher attending groups	151
6.7 Teacher interactions with groups: Opportunities for learning	159
6.8 Student interactions with the teacher during group visits: Opportunities for learning	162
7.1 Group activities during group work time	164
7.2 Graph showing number of utterances by Focus Group students during the series of lessons	167
7.3 Group activities during group work time	171

Figure		Page
7.4	Graph showing number of utterances by Focus Group students during the series of lessons	173
7.5	Group activities during group work time	181
7.6	Graph showing number of utterances by Focus group students during the series of lessons	184
7.7	Focus groups: Opportunities for learning	196
8.1	Summary of activities and interactions which provided opportunities for developing understanding of Proposition 5.	203
8.2	Circuit which did not make the globe brighter	210
8.3	Summary of activities and interactions which provided opportunities for developing understanding of Proposition 5.	212
8.4	Teacher and student behaviours during the teaching of Proposition 5	218
8.5	Focus questions given to the groups in Lesson 1 a.	220
8.6	Summary of activities and interactions which provided opportunities for developing understanding of Proposition 2.	223
8.7	Summary of activities and interactions which provided opportunities for developing understandings of Proposition 3.	232
8.8	Teacher and student behaviours during the teaching of Propositions 2 and 3	237
9.1	Graph showing class mean percentage scores on pre and posttests by proposition	239
9.2	Graph showing Focus Group members' percentage scores on pre and post tests by proposition	240
9.3	Graph showing class mean percentage scores on pre and posttests by proposition	251
9.4	Graph showing Focus Group members' percentage scores on pre and posttests by proposition	251
9.5	Graph showing class mean percentage scores on pre and posttest by proposition	262
9.6	Graph showing Focus Group members' percentage scores on pre and posttests by proposition	263
9.7	Graph showing percentage mean scores for the pre and posttests for the three classes	274
10.1	Relationship between assertions, general assertions and overarching assertions, and focus of general and overarching assertions	282
10.2	Teaching and learning for conceptual growth and change: Aspects that may affect learning including those generated by this study	308

CHAPTER 1

Background to the study

Introduction

There is a long history of research on teaching in science classrooms, with studies examining both teaching and learning. Often the investigations have found that the teaching and learning did not produce the expected outcomes, with various aspects of the learning environment recognised as being problematic. Many problems arise from the alternative frameworks that students and sometimes teachers hold, but others are caused by communication breakdowns, where the topics of discussion or the language used are misunderstood by the students and/or the teacher.

Alternative conceptual frameworks in science have been a frequent subject for research as has the development of strategies intended to restructure student conceptions towards a more scientific view (eg. Osborne & Freyberg, 1985; Posner, Strike, Hewson & Gertzog, 1982). In the literature a variety of names have been used to describe the misunderstandings students hold including: misconceptions (Helm, 1980), children's science (Osborne, 1980), intuitive knowledge (Strauss, 1981), preconceptions (Clement, 1982) and alternative frameworks (Driver, 1981). For the purpose of this thesis they will be referred to as alternative frameworks or alternative understandings.

Most teaching strategies emerging from the research have a large oral language component where the teacher and students discuss their ideas and the results of investigations and clarify these ideas. These discussions have been shown to be an important factor in facilitating conceptual growth and change (Cosgrove & Osborne, 1985b; Driver, 1989).

It has been demonstrated that, not only are teachers often unaware of the alternative frameworks that students hold and the effect that these might have on learning (Smith & Neale, 1989), but that teachers, particularly primary teachers, may hold similar alternative frameworks as their students (eg. Gilbert, Osborne & Fensham, 1982; Heller & Finley, 1992). Primary teachers often feel insecure teaching science and Schmidt and Buchman (1983) felt that they were aware of their limited knowledge and understanding. Anderson and Smith (1987) stated that only 22% of elementary teachers considered that they were competent to teach science, and Smith and Neale (1989) summarised earlier studies to conclude that primary teachers did not consider that they

had sufficient training to be comfortable teaching science and, because of this, science was not allocated much teaching time. Studies have indicated that nearly a third of primary teachers in one area of Western Australia were not motivated to teach science generally and over a third were not confident teaching energy topics (Yates, 1988; Yates & Goodrum, 1990). In a later unpublished study, 136 primary teachers in 15 schools in Western Australia were asked to indicate on a Likert scale their confidence in teaching science. Twenty-five percent of respondents had low or very low confidence and a further 32% were at the mid-point (Happs & Coulstock, 1995).

Primary school teachers in Western Australia still tend to use traditional methods for teaching science with limited or no focus on the existence of alternative frameworks, although the introduction of the "Primary Investigations" (Australian Academy of Science, 1994) curriculum may be changing this. The Western Australian primary science materials that were in schools at the time of this study, (eg. Western Australian Education Department, Curriculum Branch, 1976, 1983, 1984) had emphases on hands-on activities and group work, with questioning and discussion to promote understanding.

Oral language in primary classrooms has been investigated in many learning areas (eg. Brown & Palinscar, 1989; Cazden, 1986), with some relating to primary science lessons (eg. Bell & Freyberg, 1985; Edwards & Mercer, 1987). Investigations in high school science classrooms have analysed several language areas including teacher questioning (eg. Wilen, 1987), interactions in group work (eg. Barnes & Todd, 1977; Webb, N., 1985) and student misunderstanding of language used by teachers (eg. Bell & Freyberg, 1985; Lemke, 1990).

Conceptual change teaching strategies designed to address alternative frameworks have a large language component which is important in restructuring students' ideas. A variety of language factors may affect the development of students' conceptions, including teacher and student misunderstandings of science concepts, everyday meanings being ascribed to science terms, and the limited ability of children to participate effectively in discussions because of their limited social, interpersonal and communication skills. It would therefore appear that an investigation of oral language interactions and their relationship to the development of students' conceptions in primary science lessons, would contribute to improving science education. This may lead to an improved understanding of the types of classroom interactions that provide

opportunities for learning and facilitate the construction of scientific conceptions embedded in appropriate scientific language.

Significance of this Study

To improve the various forms of discussion in primary science lessons, more information is needed to assist teachers in structuring lesson interactions to facilitate more effective science learning. Research is needed to examine the development of meaning through classroom interactions and those that occur in group discussions. Part of this development may not be verbalised or written down, but language-based interactions within the lessons should indicate some aspects of the construction of meaning. This research investigated the oral language interactions and written work within science lessons in three primary classrooms, to begin building an understanding of the effect of classroom interactions on opportunities for learning and on the development of students' understanding of science concepts.

Purpose of this Study

The purpose of this study was to investigate the influences of teachers' and students' language and interactions in teacher-class, teacher-group and within group discussions on opportunities for learning and the development of students' understanding of electric circuits in primary science lessons.

Research Questions

Primary Research Question

How do interactions and discussions in primary science classrooms and the language used by teachers and students affect the opportunities for learning and the meanings that students construct for science concepts?

Secondary Research Questions

1. How does the teacher present the science topic and offer initial explanations and instructions for activity work?
2. How do the discussions that take place between students during group activity work and the way the activities are managed affect student participation and the opportunities for learning?
3. How does the teacher interact with groups and how does this influence the teacher's and students' participation and opportunities for learning?

4. In whole-class settings, how does the teacher conduct the discussion to bring together the reports of group discussions and develop scientific understandings, and what factors influence the students' participation and the opportunities for learning?
5. What understandings of science concepts do students develop and how are these embedded in their language?

This thesis describes the research approach and gives detailed information about the teaching and learning behaviours in three primary science classrooms and the changes in students' understandings. It also discusses the findings and suggests ways that these could be used to help improve science teaching and science curriculum and gives direction for further research. Chapter 2 reviews the literature related to the study and provides the conceptual framework; Chapter 3 discusses the methodology and steps taken to ensure the rigour of the study and the trustworthiness of the data; Chapters 4 - 7 provide information about the participating schools and the participants, the types of teaching and discussion that occurred in whole-class discussions and when teachers interacted with groups, and the discussion and work that occurred in one specific group of students in each of the classes; Chapter 8 compares two teachers' methods of teaching one proposition, and one teacher's method of teaching two different propositions; Chapter 9 examines the changes in understanding that occurred for each proposition for each class; Chapter 10 discusses the findings from the study and synthesises assertions developed from the data; and Chapter 11 discusses the limitations of the study, the conclusions that have been reached and the implications of the findings.

CHAPTER 2

Literature Review

Introduction

Students come to science lessons with strongly held alternative science understandings and often do not change these views during or after teaching (Solomon, 1993; Treagust, Duit & Fraser, 1996). Many models of and approaches to teaching science have been developed from a constructivist perspective to bring about conceptual change (eg. Cosgrove & Osborne, 1985a, 1985b; Driver & Scott, 1996). However, in the complex milieu of classroom life, a variety of factors may affect any change of views: the nature of the class discussions and the teacher's teaching style within discussions and activities; the composition of groups; students' conceptual frameworks; students' experiences in group work and the nature of the conversation in the groups; the organisation of the lesson; and the nature of students' participation in all facets of the lesson. This Chapter reviews the theoretical and research literature that informs our current understandings of teaching for conceptual growth and change.

Constructivism

Social Constructivism

Constructivist psychology considers that learners, when presented with new information, need to participate actively in relating the new information to ideas already held, in order to construct meaning from their experience (Driver, 1989, 1994; Driver, Asoko, Leach, Mortimer & Scott, 1994; Wells, 1989). Solomon (1987) discussed the move away from an earlier view based on Piaget's work that understandings were developed through personal experiences and knowledge, towards a view that understandings were socially constructed, with people needing recognition from others that their ideas are understandable and acceptable. This makes socially constructed learnings very resistant to change, and she questioned whether idiosyncratic understandings can survive in a social environment when they are not understood or accepted by others. She considered that it would be difficult to develop understandings without the cooperation and support of others. Berger and Luckman (1967) also indicated that, to validate any developing understandings, the support and corroboration of others is needed.

The concept of social development of understanding is one that was being considered as early as 1938 in Dewey's work. Although Dewey's emphasis was on the Progressive School Movement, he discussed the social aspects of learning and considered that education occurs through experiences and that there was some transaction occurring between the individual and the experience (Dewey, 1975). Pope (1981) described this as "interaction with the environment" (p. 9). In a later paper, originally published in 1944, Dewey (1966) stated that learning is affected by the attitudes and interests of other people, and that the quality of education would depend on the involvement of an individual in a social activity. Although Pope (1981) describes Progressivism as seeing the students development as being in sequential stages and stated that this was supported by Piaget's theories, Dewey's concepts place a greater emphasis on social interactions than Piaget.

Driver et al. (1994) discussed a range of views about constructivism starting with personal construction of meaning, stating that this would require classroom activities that would challenge the student's understandings and lead him/her to reorganise these. They discussed Piaget's constructivist views, which generally focussed on individual construction of meaning, and indicated that Piaget considered that social interaction could play a part in constructing understandings. Piaget also stated that, although most of his publications dealt with cognitive development, there was more emphasis on social aspects in his early studies (Kamii & DeVries, 1980). Driver et al. also discussed views of constructivism in which learners needed to develop an understanding of scientific language and practices before they would be able to construct understandings and, because science concepts are often abstract and not observable, learners need to be "initiated into the ideas and practices of the scientific community ..." (p. 6) in order to be able to develop understandings. Bruner (1985) discusses the "symbolic world" (p. 32) that is part of Vygotsky's ideas, a world which would be impossible to understand without the help and support of others. Driver et al. related this to the abstract nature of science concepts. They considered that social interaction in groups based around appropriate activities with the teacher's facilitation was an important aspect of social constructivism but, although the learners need to be involved in social interactions to develop understandings, they also need to make personal sense of the input.

Within a society, the knowledge that needs to be passed on to the new generation is learned in a social context by engaging in activities and interactions with the current

user (Berger and Luckman, 1967; Vygotsky, 1962). Luria (1976) considered that human mental development is closely linked to social practices and stated that “some mental processes cannot develop apart from the appropriate forms of social life” (page 10). Vygotsky (1956) discussed the social and mental learning that occurs in the home by way of discussion and household tasks, with the child being guided by the more skilled adults. However, he recognised that the learning that occurs at home is constrained by the space, the range of activities available and the number of adults and considered that the ideal school would be one which could support and build on the child’s ideas and understandings. Bruner (1985) emphasised that Vygotsky saw learning as a social process and not something which is occurred in isolation.

Many aspects of social constructivism relate to the “zone of proximal development” (Vygotsky, 1965, p. 103) a concept that has important implications for learning. Vygotsky (1965) described an investigation where students were given problems which they would be unable to manage on their own, but who were offered support in the form of assistance or leading questions. The students were able to solve harder problems but the difference between their mental age and the age at which the problems would be likely to be solved varied, with one student only able to advance one year and another four years. Vygotsky labelled this difference in the mental age of the student and the age of his/her problem solving with assistance as the “zone of proximal development” (p. 103). Bruner (1985) described Vygotsky’s zone of proximal development as being a situation where the learner is supported by an adult or competent peer to move from his/her current level of thinking to a higher level. The tutor acts as the “vicarious form of consciousness” (p. 24) until the learner has internalised the necessary understandings. However, the support needs to be at an appropriate level for the learner. This support is often referred to as ‘scaffolding’ (Bruner, 1985; Driver, 1989). Newman, Griffin and Cole (1989) considered that the concept could also include a situation where a group of people worked cooperatively on a problem which one or more members of the group would not be able to solve alone.

Social Constructivism in the Classroom

Brown and Palinscar (1989) describe the use of scaffolding in their reciprocal teaching of reading. Students work in cooperative learning groups with a teacher supporting the group activities. The students take turns at being the discussion leader who has the task of asking questions on the main content and summarising the content covered when the group time concludes. The teacher supports and scaffolds the

discussion as the expert in the group, but the group members are expected to jointly construct understandings and support each other in the development of these.

Crawford (1995) describes two studies related to classroom computer work. The first was with preschool children and, although initially the computer work was constrained by close supervision and instructions by adults, when the students were given more freedom any new discoveries by the computer user were observed and quickly used by others in the group, demonstrating how social interaction was able to increase the students' understanding of computer processes. The second study was with 12 year old female students, who were allowed the opportunity to use computers in an after-school club. The students were unused to collaborative work and the freedom to interact with others, and the patterns of conversation were markedly different in the club situation to the classroom. Crawford stated:

Thus, as the project evolved, the social characteristics of the setting - the shared ZPD - for learning ... involved problem definition, argument, strategic decision making, risk taking and experimentation and self evaluation in a collaborative peer group. (p. 56)

Crawford also noted the students' enthusiasm for the tasks and the learning that occurred.

Origins of Alternative Frameworks

Vosniadou and Brewer (1987) stated that, although some learning is totally new, most is incorporated into or changes current understandings, a view consistent with Piaget's concepts of assimilation and accommodation. They felt that misconceptions arise from the learner's attempts to interpret and integrate new information with their current understandings. The Generative Learning Model of Osborne and Wittrock (1983) is based on the notion that learners actively construct meaning in order to make sense of experiences using their current understandings. They attend selectively to the sensory input and use existing conceptions retrieved from long-term memory and their cognitive strategies to interpret the information. However, because many existing understandings are not scientifically correct, the resulting interpretations are also likely to be unscientific (Carey, 1986). Engagement in learning and the active construction of meaning is only likely to occur if the learner is motivated and takes responsibility for his/her own learning.

Conceptual Change

Strike and Posner (1992) stated that conceptions were very complex and had links throughout the owner's understandings, making them very difficult to change, as modification of one concept would mean other understandings would need to be re-assessed. Vosniadou and Ionides (1998) discussed two types of conceptual change; spontaneous, which is usually developed through social interactions, and instructional, which is developed through teaching experiences. The emphasis in this discussion will be on change through instruction.

Research over the past two decades has shown that students bring strongly entrenched beliefs, which do not have a scientific basis, to science lessons and these may distort the concepts that are being learned. It has been shown that these understandings are resistant to change (Anderson & Smith, 1987) and, although students may be able to respond with a scientific answer shortly after the learning process, within a few months they have often reverted to their previous understandings (Carlsen, 1991b; Cosgrove & Osborne, 1985a). Conceptual change is the process of developing more scientific understandings by the learners and is based in constructivist epistemology (Tyson, Venville, Harrison & Treagust, 1997). However, studies have indicated that there are differing types of conceptual change and, although they are given different names in different studies (eg. Carey, 1985; Hewson & Thorley, 1989; Posner, Strike, Hewson & Gertzog, 1982), most appear to offer similar examples. The new understandings developed by the learners may be added to, modify, or replace current understandings. It is easier to add to or extend existing understandings rather than replace them, but, when this happens, the learners are more likely to develop alternative frameworks as the new knowledge will be constrained by and affected by the old (Vosniadou, 1994). Tyson et al., after reviewing the literature, concluded that there are two levels of change, addition where information is added to existing knowledge, and revision where knowledge needs to be restructured. They state that most theorists separate this into "weak revision" or "strong revision" (p. 389) and include a table listing the various points of view. Weak restructuring results in limited changes to concepts whereas strong restructuring may result in the total understanding being reassessed. To replace understandings is more difficult and studies have indicated that this is a long-term process and cannot be achieved through one or two lessons, with Villani (1992) indicating that, to attain conceptual change, any new instructional

strategies need to be used over a long period of time and within a variety of activities. Vosniadou and Ionnides (1998) also support the idea that conceptual change is a gradual process which takes place continuously.

The Conditions Necessary for Conceptual Change

Posner et al. (1982) investigated conceptual change and considered that there were specific conditions required for it to occur. They considered that, for conceptual change to take place, the learner must develop a dissatisfaction with his/her current understandings, usually because they are unable to be applied satisfactorily to the situation under consideration; the new concept needs to be intelligible and understood by the learner; it must also be plausible, it must fit with developing understandings and make sense to the learner; and, lastly, the new concept must be fruitful and able to be applied to new situations. Posner et al. also considered that not all concepts are changed in the process of conceptual change, some are retained and help guide the process. These conditions have provided the basis for much research and many teaching strategies and Tyson et al. (1997) argued that this work has dominated the area of conceptual change in science because it took into account "students' epistemological commitments to their understandings" (p. 391) as well as providing practical ideas for researchers.

Conceptual change teaching strategies that have been developed since Posner et al.'s (1982) paper, generally take similar aspects of teaching and learning into account (eg. Cosgrove & Osborne, 1985b; Driver & Scott, 1996). These strategies involve the students in metacognitive processes to encourage them to recognise their own understandings; class discussion and evaluation of these understandings; presentation of the scientific understanding if it has not been offered by the students; group activities which might include experimental testing of ideas and discussion; and a bringing together of understandings developed during the activities. The activities and the discussion are specifically designed to challenge existing ideas and lead students to a more scientific understanding of the topic. Although these strategies often encouraged conceptual change it was found that students frequently applied the new understandings only in the school situation and did not use them in out of school environments (Anderson & Smith, 1987; Driver & Oldham, 1986), and that, within a short period of time, some students had reverted to their original ideas in all situations (Cosgrove & Osborne, 1985b).

Metacognition

Learners construct new understandings by interpreting what they see and hear in terms of their current concepts (Treagust, Duit & Fraser, 1996). To be aware of their current understandings, students need to develop metacognitive awareness and, to achieve this, they must be able to reflect on their own and others' understandings (Spada, 1994). Vosniadou (1994) suggested that teachers need to give students opportunities to verbalise their ideas and test them practically to help improve their metaconceptual awareness, as students are often not aware of the explanatory frameworks that they hold (Vosniadou & Ionnides, 1998). Pintrich, Marx and Boyle (1993) suggested a variety of metacognitive awareness raising strategies including paraphrasing, summarising and concept mapping which they felt would be helpful in developing understandings. Hewson and Thorley (1989) suggested that questioning by the teacher would encourage learners to reflect on their understandings, but they also felt that if students could be taught to monitor their own thinking about the intelligibility, plausibility and fruitfulness of new ideas it would provide a useful method of assisting conceptual change. Pintrich et al. (1993) considered that students at all levels of education who were intrinsically motivated and students who were focussed on learning and understanding would be likely to use metacognitive strategies. Those who were focussed on recalling information for examinations or competing against other class members were less likely to use them. Duschl and Gitomer (1991) suggested that requiring students to record their reflections and thoughts as well as the activities and observations would encourage metacognition, and felt that teaching students to assess their learning would then enable them to monitor the status of the conditions set down by Posner et al. (1982).

Ontological, Epistemological and Social-affective Aspects

Since Posner et al.'s 1982 seminal paper, other studies have indicated that conceptual change is a more complex process and the epistemological factors suggested by Posner et al. are only part of the process. Strike and Posner's (1992) paper extends the thinking to include motivational and social-affective implications. Solomon (1987) felt that the social environment had an impact on learning, affecting how the learner perceived the task and how it would be considered. Tyson et al. (1997) considered that the ontological, epistemological and social/affective aspects of learning all need to be considered.

Ontological beliefs are described in Tyson et al. (1997) as “beliefs about the fundamental categories and properties of the world” (Chinn & Brewer, 1993, p. 17) and “how children imagine the nature of objects and events” (Bliss, 1995, p. 160). Driver et al. (1994) point out that children’s ontological understandings are not static but change as the children engage in new experiences within their culture. Often the ontological categories that are used by a student to classify concepts are incorrect and these are the basis on which other understandings are built. It is therefore necessary to address these to provide a framework for the development of more scientific understandings, particularly when concepts are very resistant to change (Tyson et al., 1997). Vosniadou (1994) referred to “a framework theory of naive physics” (p. 46) and considered that this included epistemological as well as ontological presuppositions. However, she states that the understandings within the framework need to be recognised and addressed or scientific learning will not occur.

Tyson et al. (1997) described epistemology as “...how students view their own knowledge; that is, looking inwards and making qualitative judgements and commitments about various theories and conceptions they might have” (p. 400). They considered the conditions necessary for conceptual change as set out by Posner et al. (1982) a good example of an epistemological approach but felt that many studies did not evaluate the changes effectively by examining the status of the conceptions held. Duschl and Gitomer (1991) considered the learner’s epistemological framework was an important factor in achieving conceptual change as, in a classroom situation, this would affect the aspects of an investigation a learner might consider supports or negates a new understanding. Treagust et al. (1996) felt that students often have a passive view of learning and expect to memorise information supplied by the teacher. This is not conducive to conceptual change which requires students to evaluate their own and others’ understandings.

Tyson et al. (1997) felt that little attention had been paid to the motivational and affective aspects of conceptual change learning. Driver and Oldham (1986) argued that there needed to be a supportive learning environment where the teacher and students accepted the ideas proffered by others. However, Pintrich et al. (1993) considered that cognitive models of student learning did not recognise that classrooms have an important social/affective dimension, and that peer and teacher input would affect understandings. Strike and Posner (1992) agreed and stated that “While scientific concepts may be human constructions, they are predominantly social constructions into

which the young are initiated" (p. 170). Driver et al. (1994) also recognised that students need to mutually construct understandings and Driver and Oldham (1986) suggested that a supportive environment where ideas are accepted is important. Caravita and Flaldén (1994) felt that classroom environments do not often lend themselves to situations where there are shared discussion and goals, a supportive climate and a recognition that the interactions with the teacher are mutually constructed and not explanations or understandings that are imposed. Student objectives often do not relate to teacher objectives with students being more interested in obtaining the information necessary to pass examinations than in developing scientific understandings, and, without the students' active engagement in learning, conceptual change is unlikely to occur (Pintrich et al., 1993; Strike & Posner, 1992 ; Villani, 1992). The students may also be more interested in achieving social goals rather than academic ones (Linn & Burbules, 1993; Pintrich et al., 1993). Tasks set by the teacher need to be interesting to the students and motivate the students' desire for better understanding; need to relate to the students' goals; and should be meaningful and authentic, which is often difficult in the classroom situation (Pintrich et al., 1993; Villani, 1992). Pintrich et al. suggested that open-ended tasks are more likely to engage learners, but when time restrictions are in place, students tend to look for immediate answers and spend less time thinking. Pintrich et al. also considered that assessment methods are often not conducive to the acquisition of conceptual understanding.

Mental Models

The understandings that learners bring to the classroom are socially reinforced and Solomon (1987) used Schutz and Luckman's (1973) descriptor of 'life world knowing' to emphasise that these understandings are those which are used in everyday conversations and situations. Conceptual change teaching strategies were expected to replace these understandings with a more scientific view. However, these understandings are essential for interaction in the community and scientific and everyday understandings need to be held side-by-side, with the user aware of when to use each type of understanding and the limitations of each (Driver et al., 1994; Solomon, 1993; Spada, 1994; Tyson et al., 1997). Villani (1992) considered that it would be normal for students to retain their original ideas while developing their new understandings, as the process of developing new scientific understandings is long and requires many appropriate activities before they are accepted and used by the learner. However, students are likely to continue to use their spontaneous ideas in science

lessons unless specific problems are set by the teacher that indicate otherwise. Villani considered that learners are unlikely to fully accept the new scientific understandings until their fruitfulness has been demonstrated in a number of contexts. Vosniadou (1994) referred to multiple mental models and considered that differing contexts were likely to bring differing mental models into play.

A variety of aspects interact to help produce conceptual change. The classroom needs to have a social constructivist focus, with the teachers and students interacting in whole-class and small group discussions. This should provide the opportunities for learning which will result in conceptual growth and conceptual change.

Whole-Class Discussion

Solomon (1989) felt that class-teacher interactions in the form of discussions and brainstorming provided opportunities for students to demonstrate their understandings and teachers to help the students move towards more scientific understandings. Unfortunately, class discussions appear to the students as situations requiring correct answers rather than their thoughts and ideas, and teachers, even when attempting to conduct an open, pupil led discussion, often constrain the direction and content of the discussion. Within whole-class discussions different types of interactions occur; these are described below.

Teacher Explanations or Monologues

Lemke (1990) considered teacher monologues are used to provide information, give explanations, relate anecdotes or stories, give a long answer to a student question or summarise a discussion. He also considered that, because of the emphasis on student participation, teachers now prefer to use dialogue with the students to develop understandings rather than monologues. Ogborn, Kress, Martins and McGillicuddy's (1996) descriptors were similar to Lemke's but they considered explanations could also involve teacher/student questioning and responses. When trying to develop explanations using input from the class, they suggested teachers need to use cues or leading questions to obtain the required answer. They considered that teachers use their knowledge of the class to decide how explanations would be presented, and use resources or demonstrations to assist in clarifying explanations; and analogies, metaphors and stories to develop understandings. Ogborn et al. considered the teacher's pedagogic style influences the amount of input students have and the number of questions which would be accepted, answered and incorporated into the discussion, with some teachers

directing their discussions so that the only student input consists of responding to questions. They stated that teachers need to relate their explanations to real life and to understandings students have, but also need to develop scientific understandings by using scientific terms in context and encouraging student use of them, rephrasing as necessary to clarify meaning. However, if students do not fully understand the rationale behind the terms, they may use them with little understanding. Teachers sometimes provide information about a topic when it is first introduced before the students have developed any understanding, indicating that students will learn what the terms mean and about the topic. However, Berliner (1987) stated that explanations need to relate the new information to that already known by the students. He also stated that teachers should avoid vague terms, be explicit, give examples where possible, and link the explanations together. Berliner and Rosenshine (1977) emphasise the need for links between lessons to relate the current information to that from past lessons, with Tasker's (1981) study emphasising the need for teachers to make strong links between lessons.

Discussions

Discussions should allow more student input and less teacher input (Wilén, 1987) with Gage and Berliner (1992) suggesting they should be slower paced with higher order questions and that teachers needed to use appropriate lead-ins and questions. Wilén described a discussion as "...an educative, reflective and structured group conversation with students" (p. 25) while Gage and Berliner considered discussions should allow teachers and students to share opinions and clarify issues, relate new knowledge to current knowledge, answer a question or solve a problem. They also stated that teachers should take a lesser role in discussions, acting as a facilitator, and should be less judgmental and dominant. Rowe (1987) considered that discussions provided opportunities for the development of understandings, skills, attitudes and values and should demonstrate reflectiveness, responsiveness, diversity, clarity, evidence and consistency. Swift, Gooding and Swift (1988) quoting from the Dictionary of Education (Good, 1983), described guided discussions as:

...a method of teaching by which students develop an understanding of the subject through discussion of pertinent points related to that subject; their discussion is generated and guided by the instructor who uses various types of questions to do this (p. 187).

Many researchers consider that true discussions rarely occur in classrooms (Doyle & Carter, 1987; Gage & Berliner, 1992; Swift et al., 1988; Wilén, 1987) with

Swift et al. stating that the discussion is usually a lecture, drill or inquisition, with teachers dominating the talk and asking low-level questions, and both Gage and Berliner and Swift et al. arguing that they are often recitations. Lemke (1990) considered that, within science lessons, true discussions or discussions where students respond to other students' comments rarely occurred.

Within discussions, Gage and Berliner (1992) and Wilen (1987) considered that questioning by the teacher could inhibit discussion whereas statements encouraged it. Swift et al. (1988) quoted Rowe's (1978) suggestion that neutral comments encouraged further discussion but approval or disapproval inhibited it and, although they partially agreed, they felt that neutral remarks could be either bland or encouraging. Berliner (1987) and Doyie and Carter (1987) found that teachers sometimes kept the discussion going by calling on high-ability students and by ignoring lower-ability students, or accepting incorrect answers. They also stated that student involvement was often low with high off-task behaviour occurring, possibly because of long student answers. Berliner (1987) found that students who participated in class discussions showed greater achievement than those who did not participate.

Recitations and Reviews

Reviews are often held at the beginning of lessons to check students' memories of the previous lesson and often consist of question and answer sessions with the questions frequently being low-level recall. These types of interaction are often used to check and reinforce students' understanding by going over previously taught material (Gage & Berliner, 1992; Swift et al. 1988) and only use high level questions infrequently (Swift et al. 1988). Recitations are the most predominant form of oral discourse in classrooms which are used to introduce new material and are an effective way for students to acquire factual information (Wilen, 1987). They consist of the teacher briefly presenting the topic and then interacting with the students, usually by questioning, with the interactions generally being short. The student response is then evaluated by the teacher and may provide the basis for further questions (Gage & Berliner, 1992). However, they can also be used to maintain teacher control of the lesson and interactions (Carlsen, 1991a; Wilen, 1987). Recitations need to be varied in pace and level and are more effective when mixed with lecture or presentation sessions (Gage & Berliner, 1992). They should focus on key concepts and include questions that stimulate students' thinking. Roby (1988) discusses 'quasi discussions' which would seem to be similar to recitations, where the teacher questions the students but also

incorporates some lecturing. He considered that the questions are often answered by a select group of students and the format does not allow students time to reflect on the answers.

Questioning

Questioning in classrooms is a topic about which much has been written with many studies stating that the number of teacher questions in a classroom is very high (Berliner, 1987; Carlsen, 1991a; Gage & Berliner, 1992; Shuy, 1988; Wilen, 1987) although very few questions are asked by students (Berliner, 1987). Berliner reported that about 150 questions per hour may be asked by a teacher in primary science lessons, and referred to studies which indicated there was a moderate positive effect on achievement related to the frequency of questions. Carlsen citing Lemke's (1982) report stated that the frequency of questions was not consistent throughout lessons with some situations including many questions and others less. Gall and Rhody (1987) reported that research had shown that questioning is an effective supplement to teaching with some studies indicating that oral questioning is better than written.

Levels

There is a general recognition that types of questions vary and they may range from low level recall questions to higher level questions which encourage thought and reflection from the student. Questions are often categorised using Bloom's taxonomy, a hierarchical categorisation ranging from Knowledge to Evaluation. Cunningham (1987) distinguished between factual recall questions and conceptualisation-level questions. Factual recall questions require the students to remember specific information and rely on rote memory. Conceptualisation-level questions may be convergent or divergent. Convergent questions are more demanding than factual recall but are closed and narrow because little diversity is expected in responses. Low convergent questions require students to put facts together and construct a response, with high convergent questions encouraging students to reason, look for evidence to support an answer, give reasons, or draw conclusions. Divergent questions require more variety of responses and the respondees may produce imaginative or unique answers; low divergent questions ask students to think of alternative ways to tackle a problem and high divergent questions encourage creative and high level thinking. Evaluative questions may be in any of the above categories. Farrar (1988) considered that questions are not always able to be described as high or low level but may be both, and that one high level question may also be addressed by using a series of lower level questions. Gage and Berliner (1992)

stated that questions are only at a higher cognitive level if students have not experienced the question before, and, if the topic has been covered, the question is a recall question. Cazden (1986) refers to a study by Barnes, Britton and Rosen (1969) which referred to pseudo-open questions and cites an example where a teacher asked a question worded as an open question but actually required one specific answer.

Openness

There are usually far more lower level questions asked in the classroom than higher level with Shuy (1988) considering that it is possible for teachers to conduct lessons without asking any open-ended questions. Most studies have shown that about 80% of classroom questions are lower level questions (Cunningham, 1987; Gage & Berliner, 1992). Studies examining the effect of higher order questions on student learning have shown ambivalent results with various hypotheses put forward to account for this. Gage and Berliner considered that the ambivalence in results may be related to the year level of the students as it appears that lower level questions were more important in the lower primary and higher level questions in the senior years. Gall and Rhody (1987) considered that the ambivalence might be because the researchers have differing definitions of higher order questions; the American school curriculum has predominantly lower cognitive objectives; and the types of students in the studies would have an effect on the results as greater cognitive demands are placed on students when higher-order questions are asked. Carlsen (1991a) reported on three reviews of almost the same set of studies, two of which concluded that there was no relationship between high cognitive level questions on achievement and one which considered there was. He offered three possible explanations for this ambivalence: because of the weak effect of types of questioning the results may be methodology dependent, although this seemed doubtful; higher level questions may only have an effect when several other criteria are present; or there may be confusion about whether a question was high or low level because of lack of contextual information. Wilen (1987) quoted studies which suggested that the teachers' and students' thinking was not congruent and that they both needed to be trained to use and respond to higher order questions. He found research was inconclusive as to whether higher order questioning led to higher gains in achievement, but considered that the higher level questions in the higher grades seemed to relate to higher achievement. However, Samson, Strykowski, Weinstein and Walberg's (1987) quantitative synthesis indicated that any relationship between higher cognitive level questions and achievement still remained to be demonstrated.

Criteria for quality questions

Many studies discuss the criteria for quality questions. They should be clear (Gage & Berliner, 1992; Gall & Rhody, 1987; Tobin & Capie, 1982; Wilen, 1987); relevant and purposeful (Gage & Berliner, 1992; Tobin & Capie, 1982); brief (Gage & Berliner, 1992); well sequenced (Gage & Berliner, 1992); and at a variety of cognitive levels (Tobin & Capie, 1982; Wilen, 1987). Cunningham (1987) suggested that some questions need to be planned before the lesson to ensure appropriate higher level questions are asked. Lemke (1990) considered that teacher questions are often preceded by teacher preparation for the question, such as explanations and demonstrations. Cazden (1986) refers to similar verbal activities as preformulating. Students should be encouraged to respond rather than avoid questions (Wilen, 1987) but it is suggested that teachers avoid telling the students to 'think' when no immediate response is forthcoming or using compliance statements (Gage & Berliner, 1992; Rowe 1987). Gage and Berliner and Wilen considered that teachers should share the questions between all the students and request responses from volunteering and non-volunteering students. Gage and Berliner also stated that several responses should be obtained with Ogborn et al. (1996) stating that teachers needed to allow students to put forward their ideas and compare them with those of other students, then direct the students towards the correct idea. Teachers should build on the students responses (Gage & Berliner, 1992) but, when developing understandings from student input, the teacher must have a sound knowledge of the topic in order to address all the areas the students are likely to invoke (Ogborn et al., 1996). Teachers also need to be able to lead the discussion, stimulate further contributions and ensure that it is clear whether the students' ideas are being accepted, clarified or modified, or incorporated into the final understanding (Ogborn et al., 1996). Gage and Berliner also indicate some types of questions are not appropriate, citing questions with yes/no answers, leading questions and guessing questions. Wilen (1987) considered that praise should be used discriminately with Gall and Rhody stating it should be positive and constructive.

Wait-time

The concept of wait-time has also been extensively investigated with most studies indicating that a longer wait-time enhanced students' responses both in quality and length and improved students' confidence (Berliner, 1987; Gage & Berliner, 1992; Rowe, 1987; Wilen, 1987). Gage and Berliner considered that longer wait-time is particularly relevant when higher order questions are being asked. Carlsen (1991a)

reported on studies showing the positive effects of wait-time but also felt that the long pauses may inhibit the flow of the discussion. He also casts some doubt on the relationship of wait time to higher achievement as he felt there may be other reasons for this, although other studies have indicated that there was an improvement (Rowe, 1987; Wilen 1987). Rowe also stated that increasing wait time had a positive effect on teacher questioning.

Student understandings of questions

Although the teacher's intent with specific questions is usually obvious, Lemke (1982) stated that questions mean different things to different groups in the class depending on what attention they are paying at the time. One group may be answering the question, one taking it as a reminder to get back on task and one group not hearing the question.

The Relationship between Whole-Class Discussions and Conceptual Change Learning

Whole-class discussions are an important part of conceptual change teaching with the teacher needing to allow the students freedom to suggest answers which may not be scientifically correct. A range of views needs to be elicited so that alternative explanations can be compared and evaluated. This requires competence in managing discussions on the part of the teacher and an ability to follow the students' ideas and give them recognition.

Conceptual change teaching requires teachers to use their questions to help develop understanding. They need to ask questions which require the students to explain concepts, which will help the teacher understand the students' thinking. This should then be followed by questions which encourage the students to "... clarify and complete their explanations; compare alternative explanations; contrast specific aspects of the naive and scientific explanations; construct a scientific explanation in their own words." (Anderson & Smith, 1987, pp. 98 - 99).

Group Work

Noreen Webb (1985) considered that, although students often have limited group work skills, it is often used in schools and is often used in science because of the need to share equipment (Solomon, 1989; White, 1996). However, Kempa and Ayoh (1991), referring to the Plowden Report (1976) suggested that group work is also essential to allow teachers more time to interact with the students. They also quoted Washton

(1967) who stated that students need to work in groups to allow them to learn to work with others and collaborate in solving problems. Conceptual change teaching strategies require the students to develop understandings through discussion with their teacher and their peers, which provides opportunities for them to explain and justify their ideas. Group work provides situations where social construction of understandings may take place and scaffolding of developing understandings may occur.

Types of Group Work

There are many types of group work including cooperative learning where a task is divided into parts with individual group members taking responsibility for these parts; collaborative learning where two or more students work together to complete a task; and tutored learning where a student takes the role of tutor (Linn & Burbules, 1993). Of these, collaborative group work is most commonly used in science. This method does not usually assign group members specific responsibilities and there is little competition between groups (Webb, N., 1985). The intention in collaborative group work is for the students to work together to complete tasks that have been explained by the teacher and they are expected to interact together to solve any difficulties, asking for and offering help within the group (Kempa & Ayob, 1991; Tao & Gunstone, 1997; Webb, N., 1985). Kempa and Ayob describe group work as “any collaborative activity involving two or more pupils that may take place in the course of a lesson and is directly supervised or controlled by the teacher” (p. 342). Linn and Burbules consider that group learning should involve two or more students working together to solve a problem and communicate in a way which would “... jointly negotiate understanding, plan complex tasks, explain things to each other, direct activities, contribute ideas, and coordinate actions with one another” (p. 92).

Effects of Group Composition

Tao and Gunstone (1997) considered that students should start at the same level of competence but many studies (eg. Webb, N., 1985) have worked with groups of students at varying levels of ability. The differing levels of ability of students in a group have an effect on the giving and receiving of help and explanations. The less able students are less likely to offer help or explanations, whilst those in the group who are comparatively more able, regardless of whether that ability is high or not, are more likely to, with the most able in the group offering the most explanations (Webb, N., 1982, 1985). Extroverted students are more likely than introverted students to succeed in obtaining answers to their questions (Webb, N., 1985) although Kempa and Ayob

(1995) also found that extroverted students engaged in more off-task interactions and suggested that they may be less likely to pay full attention to other students' contributions. Off-task behaviour may also be exhibited by students with a low academic self-concept in situations when they need to manage their own time and activities (Anderson, 1984).

Lower ability students or students who were less able to think scientifically, in group work tended to follow the judgements of the more able students (Richmond & Striley, 1996; Webb, N., 1982). Richmond and Striley also found that students who had experienced less success in the activities were less likely to be listened to and were more likely to change their view to agree with others.

Student gender may affect the questions asked and the explanations received. In an above-average class, boys tend to ask questions that require specific information, whereas girls tend to ask general questions which are unlikely to generate information that will assist learning (Webb, N., 1985). This was not found to occur in below average classes. Richmond and Striley (1996) found that a student's academic ability and status within the school were factors that affected the acceptance of their ideas by others and suggested that the students who found it difficult to put their understandings into words would find it hard to convince other students that their ideas were worth consideration. Unfortunately, any explanation offered by students with high social status is often accepted uncritically by their peers (Linn & Burbules, 1993; Solomon, 1989). However, Roychoudhury and Roth (1996) found that any group member's ideas, regardless of whether they were high status members or not, would only be accepted if they were supported by at least one other student.

Gender may also affect the work done by group members. Many studies have shown that boys tend to dominate use of the science equipment in group work (Kahle & Lakes, 1983; Whyte, 1984) and girls may be disadvantaged because they do not have access to the equipment and they may be given the task of recording rather than physically using the equipment. If they do have access to the equipment they may find the task too difficult, become frustrated and move on the written work that is required (Tasker 1992).

Time on Task

Studies indicate that generally the amount of learning that occurs is related to the amount of time on task (Bennett, 1987; Myers, 1990; Ross, 1984; Walberg, 1988) with Bennett also stating that the relationship is not consistent. Walberg also considered that

time-on-task is only one factor that affects learning with others, such as aptitude, teaching and the appropriateness of the task level, also playing a role. Bennett stated that “Time is a necessary, but not sufficient condition for learning” (p. 72) and then discussed the lack of research on the quality of the teaching and learning that might occur within the allocated time. Myers (1990) reviewing Rosenshine and Berliner’s (1975) research, stated that they found that ensuring that students stayed on-task during a lesson should be a “primary objective of the teacher” (p. 16). Bennett considered that the teachers should ensure the students are attentive and are using the time effectively with Myers considering that teachers’ classroom management skills should be such that they improve time-on-task.

Off-task behaviour can be a problem with group work as it was found that students tended not to be as involved in work when a teacher was not present, although it improved with the presence of the teacher (Anderson, 1984; Berliner & Rosenshine, 1977; Croll & Moses, 1988). In studies where the groups were not in a normal classroom setting there was only a limited amount of off-task behaviour and this was non-significantly related to achievement. However, the off-task behaviour in normal classroom settings was higher and there were significant negative relationships between off-task behaviour and achievement (Webb, N., 1982). Kempa and Ayob (1991) commented on studies by Boydell (1975) and Galton, Simon and Croll (1980) which showed that the group talk was frequently unrelated to the task, although in their own studies, students’ on-task behaviour was generally good. However, the studies were conducted in a Malaysian school where discipline is emphasised and the students were aware that their group work was being observed for the study. Rennie (1990) considered that excess time for which work had not been organised was used for off-task behaviours. She also considered that the seating arrangements affected the attention students paid during whole-class discussions as, when they were seated in groups around tables, the students were less likely to turn and face the teacher. Roychoudhury and Roth’s (1996) study showed little off-task behaviour which they concluded was because of the students’ ownership of the investigations.

Roles of Participants

Students

Some science curriculum materials (Australian Academy of Science, 1994) assign roles to the group members. Where roles are not assigned by curriculum materials or by the teachers, group members still take them on. Richmond and Striley

(1996) defined the roles that emerged in the groups in their study, as leaders, helpers, and non-contributors who were either active or passive. They found that leadership styles were very different with inclusive leaders trying to ensure everyone's ideas were considered; persuasive leaders trying to persuade group members that their personal ideas were the best; and alienating leaders tending to hold strong beliefs and refusing to listen to input from other group members. These leadership styles affected any discussions that took place. Groups with inclusive leaders tended to engage in more discussion of all aspects of investigations whereas the alienating leaders imposed their understandings on their group. Because the discussion was more limited in the groups with persuasive leaders, the less able members often only gained limited understandings and were constantly requesting more information. The strategies were not exclusive to the leaders with other group members also using similar tactics when trying to 'sell' their ideas. The helpers in the groups were those who cooperated with the leaders and other group members and were able to assist with planning and doing the activities. The active non-contributors tended to be off-task but were aware of the activities, often denigrating ideas (Barnes & Todd, 1977; Richmond & Striley, 1996). The passive non-contributors rarely participated and often copied other students' work (Richmond & Striley, 1996). Noreen Webb (1982) only referred to one short-term study that examined passive behaviour in a group which concluded that passive behaviour was not conducive to learning. Brown and Palinscar (1989) also recognised group roles which included the executive or doer who plans and designs; the instructor or educator who explains and summarises for the less involved group members; the sceptic or critic who questions; the record keeper; and the conciliator who helps resolve any conflicts. They considered that these group roles were spontaneously taken on by the group members, and may move among them.

Teachers

Teachers are expected to monitor the groups to ensure that they are on task and working together (Anderson, 1984), but they are also available to answer questions and facilitate the development of understanding (Driver, 1989; Webb, N., 1985). Teachers need to question the students to promote reflection and metacognition by them and to encourage them to use observations and other data to support their assertions (Driver et al. 1994). Barnes and Todd (1977) suggested that the teacher's role is to help the students clarify their thinking; to help redirect their thoughts; to encourage the students to be more self-critical; to help manage the activity; and to offer extra information when

necessary. They also stated that teachers need to listen carefully to the students and ensure that the comments and responses that they make are non-judgemental. Roth (1995) stated that, in the open-ended laboratory activities in his study, the teacher's role was that of an adviser and facilitator who helped scaffold the students' learning by asking questions that led to better understandings, and who assisted with choice and use of equipment. Roychoudhury and Roth (1996) felt that it was important for teachers to manage their time carefully to ensure that they have time to assist with difficulties but also to make sure that all the groups were visited.

Group Size and Participation

Barnes and Todd (1977) felt that the maximum size for an effective, functional group was four and found that larger groups resulted in non-participants. Kempa and Ayob (1991) found that, although participation in smaller groups was evenly balanced, in groups of four students this was less likely to be so. They found that interactions often only involved pairs of students and only a limited percentage of interactions included the whole group. They were aware of non-participants and suggested that it was possible that the non-participant may be listening and learning from the conversation but, alternatively, may not be attending to the discussions. Kempa and Ayob later (1995) analysed the learning that occurred and related this to the interactions within the group. They found that students gave information on tests that had been provided by other students in the group discussion, but they also sometimes included information that was not from the group discussion, indicating that some of their own ideas were not shared with the group.

Interactions in Groups

Few studies were found which discussed the types of interactions found in group work. However, Solomon (1991) referred to a study by Wallace (1986), which suggested six types of interaction: negotiating the organisation of the task; solving social problems, giving help or tutoring; social non-task talk; negotiating knowledge; and constructing meaning.

Roychoudhury and Roth (1996) looked at patterns of interactions in groups and separated them between symmetric interactions where members of a group took roughly equal turns; asymmetric, where turn-taking among the students was limited; and shifting asymmetric where an individual student dominated the interactions for a period of time then another student would be dominant, with students, again, having reasonably even turns.

The relative abilities of students may affect the interactions within the groups. Homogeneous medium-ability groups and heterogeneous groups gave more frequent explanations than either homogeneous high-ability groups or homogeneous low ability groups. This appeared to be because the high-ability groups seemed to put less effort into the tasks because they felt they had sufficient knowledge, and the low-ability groups did not have the skills or knowledge to effectively generate explanations (Webb, N., 1985).

Gender may also have an effect on the interactions in groups. In a study where the gender balance in the group was manipulated, it was found that if there were more girls than boys in a group the girls tended to ask the boy for help rather than another girl, with the boy often not responding. Where there were more boys than girls, the boys tended to ignore the girls' questions. The girls in both these types of groups learned less than those in a group with an even number of boys and girls (Webb, N., 1985). Stereotyping also sometimes occurred in groups with boys assuming girls lacked knowledge about science (Linn & Burbules, 1993). Barnes and Todd (1977) felt that single gender groups were better for adolescents, as polarisation tended to occur in mixed groups.

Learning in Groups

Skills for learning

Students, particularly if they feel they have limited time to complete the task, may accept the first idea that is offered (Linn & Burbules, 1993; Pintrich et al., 1993) and will often use the idea of a group member with high social status, regardless of where that status is earned (Linn & Burbules, 1993). Unless the appropriate reflection, evaluation and integration skills are taught and practised in the classroom, it is unlikely that students will use them and many students do not have the skills for effective interactions in group situations (Linn & Burbules, 1993).

Verbal interactions and learning

Some studies have shown that peer tutoring or helping within a group may increase learning, however other studies have produced ambivalent results (Webb, N., 1982, 1985). Noreen Webb (1982) argued that it is important to differentiate between the types of help given. Terminal help only supplies or corrects the answer and does not provide any background information or explanations. This type of help does not increase the learning of either helper or recipient. However, explanatory help, which describes how to reach an answer, helps the learning of both the explainer and the

recipient with Noreen Webb (1982, 1985) suggesting that the process may help the explainer reorganise and re-evaluate his/her own ideas. However, as the students who offer explanations are also the students who understand what is happening, they would be expected to demonstrate more learning (Brown & Palinscar, 1989; Kempa & Ayoh, 1995). Noreen Webb (1982) also suggested that help is only effective if it is given in response to need, that is, when it is requested. Kempa and Ayoh (1991) found that most of the group interactions in their study consisted of descriptive talk with a very limited amount of explanatory and insightful interactions. They considered that this and the results from other studies indicate that students find it hard to engage in higher level cognitive discussion.

Although some studies indicated a relationship between verbalising information and improved learning when working on a task, others did not (Webb, N., 1982). An analysis of results indicated that it is possible that the purpose of the vocalising is more important than the actual vocalising. It was found that students who responded to questions by an experimenter performed less well than those who verbalised to teach or help others (Webb, N., 1982). Roychoudhury and Roth (1996) found no relationship between the amount of interactions and the individual's learning.

Effects of social factors on learning

Linn and Burbules (1993) suggested that groups often did not collaborate productively because maintaining the social ambience of the group was more important than questioning others' ideas and students may choose to accept understandings that help to maintain group norms and social cohesion (Barnes & Todd, 1977; Linn & Burbules, 1993). Students may misinterpret the results of science investigations and draw on everyday knowledge rather than trying to understand what is happening (Linn & Burbules, 1993).

The Relationship between Group Work and Conceptual Change Learning

Collaborative working allows cognitive benefits such as articulation, conflict, justification and co-construction (Brown & Palinscar, 1989; Tao & Gunstone, 1997) and feedback and questions from other group members about concepts and resources may help students to re-organise their ideas and learn new material (Webb, N., 1982). In group work, students co-construct understandings and build on each others' ideas resulting in a Vygotskian social learning environment (Tao & Gunstone, 1997) with the collaborative environment offering students scaffolding in the Vygotskian sense because the knowledge and information owned by the group members (Brown & Palinscar,

1989; Roychoudhury & Roth, 1996) is available to the group (Linn & Burbules, 1993). However, the students as a group may still use that information to co-construct non-scientific understandings (Linn & Burbules, 1993; Solomon, 1987, 1989). Roychoudhury and Roth (1996) felt that, before being able to collaborate to construct understandings, students needed a certain level of shared understanding, a view supported by Brown and Palinscar (1989). Whilst engaged in the activities and developing shared understandings, students also need to reflect on and actively process the ideas to reconstruct them to make their own personal sense of the new ideas (Tao & Gunstone, 1997; Wittrock, 1974), and rehearsal of ideas in the form of discussions and conflict within groups may assist this (Webb, N., 1982). When conflict arises in collaborative learning situations, students are often required to provide data to justify their arguments and reflect on their ideas (Brown & Palinscar, 1989; Roychoudhury & Roth, 1996; Tao & Gunstone, 1997). As students' ideas are discussed, the questioning and criticism may lead to uncertainty and the ensuing dissatisfaction with the ideas may lead the students to make mental adjustments and cognitive changes (Brown & Palinscar, 1989). Brown and Palinscar also considered that students need to have similar social status or a more dominant member may prevail without the weaker member recognising the alternatives, and the ideas being offered must be plausible and understandable to the students.

Conceptual change teaching strategies include group work as this offers students an opportunity to discuss and develop understandings. It allows students to use metacognitive processes as they try to explain and justify their understandings to other group members and allows them to scaffold each others' learning and discuss the ideas that are offered. It gives the teacher an opportunity to interact with the students in a small group situation, recognising misunderstandings and facilitating the development of scientific ideas.

Language

Oral language plays an important part in learning (Barnes, 1976; Hayes, Stahl & Simpson, 1991; Thomson, 1978; Wells, 1981), in communicating and assessing knowledge (Ausubel, 1968; Wells, 1981) and allows students to generate new ideas and develop abstract understandings (Ausubel, 1968). Language allows students to review and manage their thought processes whilst developing an understanding of the world around them (Barnes, 1976; Bruner, 1971; Thomson, 1978) and is the means by which

information presented to a person is re-interpreted by the listener (Bruner, 1985; Vygotsky, 1986). Learners need to use speech and writing in order to develop meaning, recognise their current understandings and assimilate new knowledge, (Barnes, 1976; Thomson, 1978) and in science, language provides scientific ways of discussing the topic (Lemke, 1990). Oral language is the most effective way for understandings to be manipulated and thoughts considered critically (Hayes et al., 1991). Conceptual change teaching strategies include group and whole-class discussions which require careful management of verbal interactions.

Word Meanings in Science Lessons

Research findings strongly suggest that primary teachers, as well as students, may have non-scientific meanings for words used in science lessons. Bell (1981) found that word meanings held by teachers and students for concepts such as 'animal' are sometimes limited to criteria appropriate for mammals. Words such as 'work' (Barnes & Todd, 1977, Osborne, Bell & Gilbert, 1983), 'force', 'power' and 'friction' (Osborne et al., 1983) may be defined in terms of everyday, rather than scientific explanations. Sutton (1980) suggested that the necessity for precision of meaning in science is not appreciated by children as "... for the child particularly the meaning of a word is *not* its definition. It is better thought of as the *sum of all its connections to other things he knows*" (p. 51, original emphasis). This view is shared by Vygotsky (1986) and Solomon (1987). Viegas, Costa Pereira and Maskell (1989) considered that a teacher's use of words with everyday meanings in science lessons resulted in students interpreting the information from a non-scientific perspective. There is a range of meanings for words that members of the classroom may have and they need to be addressed in ways other than just explaining the scientific meaning (Tasker, 1992).

Understanding Interactions in the Classroom

Student difficulty in understanding may extend further with students sometimes constructing little meaning from the teacher's language, particularly if the information does not relate to any understandings that they hold. However, they are often able to rote learn the words and use them in discussions (Bell & Freyberg, 1985; Lemke, 1990; Thomson, 1978; Vygotsky, 1986) and Parker (1992), described their use of scientific terminology as "expert" (p. 30) and suggested that it could hide their lack of understanding of science. Teachers often consider that science language use demonstrates understanding but are unaware that little understanding is present (Bell & Freyberg, 1985) and teachers tend to pay limited attention to the way students talk about

a topic (Lemke, 1990). Students' attempts to communicate using their own language are often not valued by the teacher (Bell & Freyberg, 1985; Lemke, 1990) although they are important as they reveal the students' understandings (Barnes, 1976; Thomson, 1978; Wells, 1981, 1989). Lemke (1990) argued that students need practice in using science language and should be able to reword their understandings to fit differing situations with Wells (1981) suggesting this practice could be achieved by students explaining their ideas to others.

Everything that is said in the classroom may be misconstrued by the listener, whether it be the teacher or a student (Lemke, 1990). Bell and Freyberg (1985) considered there were three types of language misunderstanding that may occur in science classrooms. First, unidentified mismatches occur when teachers and students are unaware that their meanings for words differ. Second, identified mismatches occur when students are aware of the science meaning but continue to use their own meanings. The third problem occurs when the meaning of words change from the everyday context to the science context, eg. "make" in the context "plants can make their own food using the sun's energy" (p. 36).

Language Links

Constructivist perspectives of learning require the learner to make links between new information and existing knowledge but it is possible that, because of the students' personal interpretations of words used, the links made by each student might be different and they would therefore construct different understandings (Lemke, 1990; Sutton, 1980). The strength of students' current understandings may affect the amount of attention they pay to the teacher's explanations as they may not attend to information that is alien to their point of view (Strike & Posner, 1992; Sutton, 1992).

The Relationship between Language and Conceptual Change Learning

All classroom activities rely on communication, and, to develop appropriate understandings, students need to be able to interpret what is said during the lesson and make appropriate links to other knowledge. The words used in science often have counterparts in everyday language with different meanings and this may result in students using the language in a non-scientific way and making non-scientific links. Students often find teacher language in science hard to interpret but are able to learn the words and use them, albeit without understanding. The emphasis on discussion in conceptual change teaching strategies and the problems students and teachers may have

with science language indicate that, to achieve change, the use of language and monitoring of student understanding needs to be carefully managed.

Teacher Knowledge

Teachers have a wide and varying range of understandings of science concepts and these may affect the learning that takes place during science lessons and the types of questions used in assessing student understanding. Although it seems reasonable that a lack of knowledge may have an adverse effect on student learning, it is also possible that teachers with good conceptual knowledge may inadvertently inhibit learning.

Teacher Understandings

Teachers' understandings may range from being similar to those of scientists to being similar to the understandings of their students. Gilbert, Osborne and Fensham, (1982) referred to the differing views of science as "teachers' science", "children's science" and "scientists' science" (pp. 624, 627, 628). These understandings are likely to interact with the curriculum materials being used, either making them closer to a scientist's view or closer to a child's view, and the teaching that then occurs may not be that intended by the curriculum planners (Arditoglou & Crawley, 1990; Gilbert et al, 1982; Smith & Neale, 1989).

Many studies have shown that teachers' understanding of science content is often scientifically incorrect and close to that of their students (eg. Arditoglou & Crawley, 1990; Bell, 1981; Smith & Neale, 1989). Hashweh (1987) found that secondary teachers teaching outside their area of expertise had similar misunderstandings to those commonly held by students and were unable to recognise the misunderstandings that students held. They also found that some teachers also held misunderstandings within their area of expertise. Wilson, Schulman and Richert (1987) considered that teachers need to not only have a good understanding of the content being taught, but also need to have enough understanding of both the content and their students to be able to facilitate learning. They need to recognise that different students will need to have the information presented in different ways and that students have differing existing knowledge when they come to the lessons. Primary school teachers often lack content knowledge in science (eg. Ginns & Watters, 1995; Kruger & Summers, 1988) and teachers have been found to not only have unscientific understandings of electric circuits and current flow, but to apply these inconsistently and

sometimes to adjust them depending on the context (Heller & Finley, 1992; Wehb, P., 1992).

The Effects of Limited Teacher Knowledge on Teaching and Learning

Lack of knowledge may not only result in students learning incorrect facts and concepts (Gilbert et al., 1982) or teachers reinforcing students' misunderstandings, (Hashweh, 1985) but may also change the teacher's style of teaching to inhibit interaction and learning (Carlsen, 1992; Dobey & Schafer, 1984; Sanders, Borko & Lockard; 1993). Studies conducted in secondary schools with novice teachers indicated that they tended to postpone starting the content section of the lesson, were more inclined to be diverted by irrelevancies and dominated classroom talk, allowing students less time to discuss, comment and question. They were unwilling to diverge from the main topic to related topics. Students' responses to questions were less likely to be evaluated firmly, texts were followed closely and teaching tended to be slower and more fragmented (Carlsen, 1992, 1993; Tobin, Rennie & Fraser, 1990). Berliner and Rosenshine (1977) stated that younger students find it hard to learn when lessons are disjointed. Many of these findings, together with others such as difficulties presenting explanations and emphasis on seatwork, were also reported in another secondary school study of expert teachers teaching outside their area of expertise by Sanders et al. They commented that "...both students and teachers sometimes ended up confused" (p. 730). They also found that teachers, reflecting on the day's lessons, were more likely to reflect on their teaching rather than student learning and were often uncertain whether their teaching was effective. It was felt that, as experienced teachers, they were often able to rectify errors in future lessons. Wilson, et al. (1987) felt that teachers need a repertoire of ways of presenting information including analogies, metaphors and examples but Smith and Neale (1989) considered that lack of understanding might result in teachers using metaphors or analogies that are unsuitable and may mislead students. This was demonstrated by Viega et al's. (1989) study, where teachers' use of inadequate metaphors and analogies reinforced students' alternative understandings.

The Effects of Sound Teacher Knowledge on Teaching and Learning

Although teachers' lack of knowledge may inhibit student learning, it is also possible that teachers with good scientific knowledge may cause difficulties in student learning. Ausubel (1968) felt that knowledgeable teachers may have difficulty rewording their knowledge so that it is understandable by primary students and may not realise that the complex understandings they hold about concepts may confuse students.

However, Sanders et al. (1993) argued that experienced teachers are able to convert their knowledge to a form suitable for students. Ausubel also considered that, once knowledgeable about a concept, teachers tend to forget any alternative understandings they may have had and the difficulties they had when learning the concept.

Dobey and Schafer (1984) considered that, for inquiry teaching, teachers with an intermediate level of knowledge provide the best learning environment. They are confident in their teaching, do not restrict children's investigations and are able to offer the students challenges. Knowledgeable teachers tend to interrupt activity work to correct the students' investigations rather than encouraging them to solve difficulties for themselves; and provide explanations rather than facilitating understanding. Teachers with little knowledge restrict the lesson activities and student discussion.

The Relationship between Teacher Knowledge and Conceptual Change Learning

The level of teacher understanding of the science being taught will affect, in a variety of ways, the learning that occurs. Discussions and questioning are important for conceptual change to occur (Driver & Oldham, 1986) and an ability to relate the concepts to other areas or to represent the information in other ways enhances understanding (Carlsen, 1991b; Sanders et al., 1993; Wilson et al., 1987). Primary students tend to treat lessons or parts of lessons as unrelated (Tasker, 1981) and any fragmentation of teaching because of limited teacher knowledge may emphasise this.

Opportunity to Learn

Originally, opportunity to learn was related to the time allocated to the curriculum (McDonnell, 1995) and Bennett (1987) expressed concern that research had not attended to the quality and appropriateness of the learning experiences and had only focussed on the amount of time allowed for learning. McDonnell reports that, during the 1980s the opportunity to learn approach extended its framework to consider the teaching/learning aspects as well as the time allowed, as research had indicated that opportunity to learn was not only defined by the curriculum but also by how the content was presented and by whom. She suggested that items for investigation should be the teacher's background and experience; the school and classroom organisation; the curriculum content; the availability and use of the instructional materials; and the instructional strategies used. Brophy and Good (1986) considered opportunity to learn to be related to the amount of time available for the curriculum content but also to the teacher's input to student learning. They listed classroom management and student

engaged time; the appropriate level of the material; and active teaching by the teacher as important factors. Tobin et al. (1990) examined two high school science classrooms and found that student engagement was higher where there were more whole-class, teacher-centred activities, with the students in the class where group work was the norm engaging in more off-task behaviours. Tuyay, Jennings and Dixon (1995), who examined collaborative story-writing in a bi-lingual classroom, felt that opportunity to learn was provided by the students' opportunities to interact with the information offered and relate that information to their previous experiences. They stated that it is important for information to be presented in a variety of ways to provide more learning opportunities. McDonnell found that many studies of opportunity for learning have been based on teacher surveys and these offered limited information, and she considered that much more research data are needed on the discourses that occur in classrooms and students' participation in the learning experiences.

Opportunity for learning may also be affected by the classroom environment. Brophy and Good (1986) suggested that teacher enthusiasm influences affective outcomes, but, particularly with older students, may also influence learning. Fraser (1991) in his summary of classroom environment research stated that many studies have found a correlation between student perceptions of the learning environment and affective and cognitive outcomes, and that students prefer a more positive classroom environment. He referred to a meta-analysis of studies which indicated that achievement was improved "... in classes perceived as having greater Cohesiveness. Satisfaction and Goal Direction, and less Disorganisation and Friction" (p. 9).

Alternative Frameworks

Many investigations have been conducted into alternative frameworks in science. Confrey (1990) stated that Pfundt and Duit (1985, 1988) found 1,500 citations with alternative frameworks appearing in all concept areas and similar misunderstandings are found internationally (eg. Fetherstonehaugh, Happs & Treagust, 1987; Webb, P., 1992). This section will only consider the alternative frameworks that have been described in the area of electricity.

Alternative Frameworks in Electricity

Batteries and simple circuits

The battery is often considered the source of electric current (Heller & Finley, 1992; Osborne, 1980) or is looked upon as a container of electric current (Osborne,

1980; Osborne & Gilbert, 1979) or a device which stores electric current (Maichle in Shipstone, 1985; Osborne, 1980) and, when included in a complete circuit, it may not be considered to have a current flow through it (Osborne & Gilbert, 1979).

Many studies have investigated the concept of a circuit. Many students and adults consider that electricity can still flow through wires which are attached to a source of electricity but are not connected to anything else (Dupin & Joshua, 1987; Osborne, 1980; Osborne & Gilbert, 1979). Primary school students and university engineering students were unaware of where connections needed to be in a simple circuit consisting of a dry cell, a light globe and one or two wires (Fredette & Lochhead, 1980; Tasker & Osborne, 1985) and 12 year old students found the addition of a globe holder to a circuit made circuit construction more difficult because they lacked understanding of circuit connections and current flow through a globe (Arnold & Millar, 1987). Fredette and Lochhead considered that some students viewed the globe as something that “energy flows into rather than through” (p. 197). It was noted that many electricity concepts, because of the abstract nature of electric current, tended to be related to personal experience (Osborne, 1980; Osborne & Gilbert, 1979) with subjects considering wires which did not have a light globe attached would have an electric current through them as experience had shown that, when the wires were touched, the toucher received an electric shock.

Where a circuit is complete there are a variety of views regarding the direction and amount of current flow. A uni-polar view considers that electric current only comes from the top of the battery or dry cell and any wires from the bottom of the battery to the globe are unnecessary (Arnold & Millar, 1987; Osborne, 1980; Tasker & Osborne, 1985; Webb, P., 1992). Even when it has been demonstrated that two wires are necessary, students may still consider that nothing occurs in the bottom wire (Tasker & Osborne, 1985). The bi-polar view suggests that current is flowing towards the globe from the top and the bottom of the battery (Arnold & Millar, 1987; Osborne, 1980; Tasker & Osborne, 1985; Webb, P., 1992) and two explanations are offered of why this is so. One explanation considers that the top and bottom wires contain different currents which are both needed to allow the globe to light (Osborne, 1980; Shipstone, 1984), a view which Shipstone considered could be changed by teaching. The other view considers that the same type of current is in each wire, with insufficient from one end of the battery to light the globe. When the current flow from the two wires is added together the globe lights normally (Arnold & Millar, 1987; Shipstone, 1984). Shipstone

considered that, as there was a decline in the prevalence of this view from Years 1 - 3 in high schools, it is remediable.

A third view incorporates the concept of electric current flowing around in a circuit but the direction of current flow may be from positive to negative or negative to positive with two views about the amount of current in the wires. One view considers there will be less or no current in the wire in which the current returns to the battery from the globe because current has been used up in the globe (Dupin & Joshua, 1987; Heller & Finley, 1992; Osborne, 1980; Tasker & Osborne, 1985; Shipstone, 1984). The second, correct view considers there is the same amount of current in both wires.

Series circuits

Reports on studies of batteries in series appear limited although Osborne (1980) found that 50% of students felt that the battery closest to the globe would have most current as the current would be building-up in that battery from the other two batteries. He considered this would indicate a uni-polar view.

Globes in series have received more attention. Some respondents consider that, because current flows in one direction through a circuit and is used up in the globes, globes further away from the initial point of flow would be dimmer (Heller & Finley, 1992; Shipstone, 1984). Respondents may also consider that, because each globe will use some of the current, all globes in a circuit will receive less current (Heller & Finley, 1992; Shipstone, 1984). Students with this view also consider globes in a parallel circuit would be dimmer. Conversely, other respondents consider that the brightness of extra globes in a circuit would be the same as that of a single globe, regardless of the type of circuit (Heller & Finley, 1992). Students with a bi-polar view may consider that, when two globes are connected in series, the globes will be dimmer as current for each globe only appears to be coming from one end of the battery - a view which is consistent with the brightness of the globes (Arnold & Millar, 1987).

Parallel circuits

Parallel circuits have received less attention, with some studies looking at more advanced understandings which are not relevant to this study. Dupin and Joshua (1987) found students from age 12 to university level tend to consider that globes in parallel would be less bright than a single globe, a finding corroborated by Heller and Finley (1992).

Terminology and understanding

Osborne and Gilbert (1979) found that when students were asked to define scientific terms related to electric current they were able to provide scientific definitions even though interview data indicated that their understandings related to the phenomena were limited. They concluded that an ability to define terms was not an indication of understanding. Students tend not to discriminate between the terms electricity, current, power or energy (Arnold & Millar, 1987).

Osborne (1980), Heller and Finley (1992) and Shipstone (1985) all found that interviewees from primary school to teacher training colleges all showed inconsistencies in their application of understandings, using one view to respond to one question and a different view to respond to a later question. This finding was also corroborated by Arnold and Millar (1987) who found responses from interviewees' explanations tended to be specific to the situation and not generalised.

Teaching for Conceptual Change in Electricity

Several studies have investigated teaching strategies to change understandings that adults and children hold about electric currents and circuits. Cosgrove and Osborne (1985b) designed a conceptual change teaching strategy which was used to teach electric circuits to students whose age range appears to be 11 - 14. Their strategy starts with a preliminary phase which allows teachers to clarify their views of the topic, recognise the scientific view and also introduces them to some of the alternative frameworks that children hold. The second phase is referred to as the focus phase and supplies activities which will allow students with little knowledge to learn some basic information and those with some knowledge to extend their understandings. Although the activities are designed so that the students can work on them by themselves, the teacher is required to interact with all the students, individually and in groups, elicit their ideas and "focus the students' understandings" (p. 113). The challenge phase is next and Cosgrove and Osborne describe this as the "...crucial phase of the teaching sequence" (p. 113). This involves the students presenting their ideas and listening to the ideas of others; reviewing their ideas; becoming involved in activities that test their ideas; and then confronting the evidence. Cosgrove and Osborne suggest that whole-class discussions are an effective way of collating student ideas and, if the scientific view is not suggested, the teacher needs to put it forward, although not as his/her own idea. They suggest that the method of testing ideas should be designed by the students

with the teacher's help. They also indicate that the test is unlikely to immediately change students' ideas as the scientific view is often the least plausible idea and that explanations and analogies may help. The last phase is the application phase where practical problems are given to the students to solve using the new idea, helping to reinforce the new understandings. Teacher facilitation is also important at this stage, to ensure students understand what is happening. Cosgrove and Osborne report that the results obtained with this teaching sequence were positive although not all students changed their views. However, they did find that, after the intervention, over time nearly half of one group of students regressed to earlier ideas.

Arnold and Millar (1987) used a constructivist approach to address a range of fundamental understandings, although they did not look at parallel circuits. Their instructional techniques encouraged the students to use their existing beliefs to formulate theories, which, if scientifically incorrect, were challenged by appropriate activities to generate conceptual conflict. When the situation was such that the scientific view was needed to help understand the situation, it was offered and elaborated upon, with the students encouraged to re-examine their understandings. Most of the teaching was in small groups with individual attention as necessary. The students' understandings were checked one week after the teaching was completed and there was an improvement over all areas of concern. However, students are likely to revert to their initial understandings and there is no mention of a delayed posttest, so it is impossible to confirm that these were long-term changes.

Summary and Conceptual Framework

Social constructivism provides a view of learning which encompasses all the activities and interactions in the classroom and allows opportunities for learning to occur. It can be summarised as including the interactions that occur between teachers and students, and within groups of students, in the whole class and in group discussions and activities (figure 2.1). Within the framework of social constructivism, the participants, the teacher and the students, interact in a variety of ways. The teachers offer input and ascertain understandings through the whole-class discussions and, at the same time, are developing an understanding of the concepts students hold. They can then use this knowledge to design whole-class and small group activities and discussions which provide opportunities for new learning to occur and which will scaffold the students' further development of understandings. At the same time as the

students are obtaining new information they are also recognising the understandings that other students in the class hold, as well as putting forward their own ideas and understandings. These opportunities for learning facilitate the conceptual growth or change of the students.

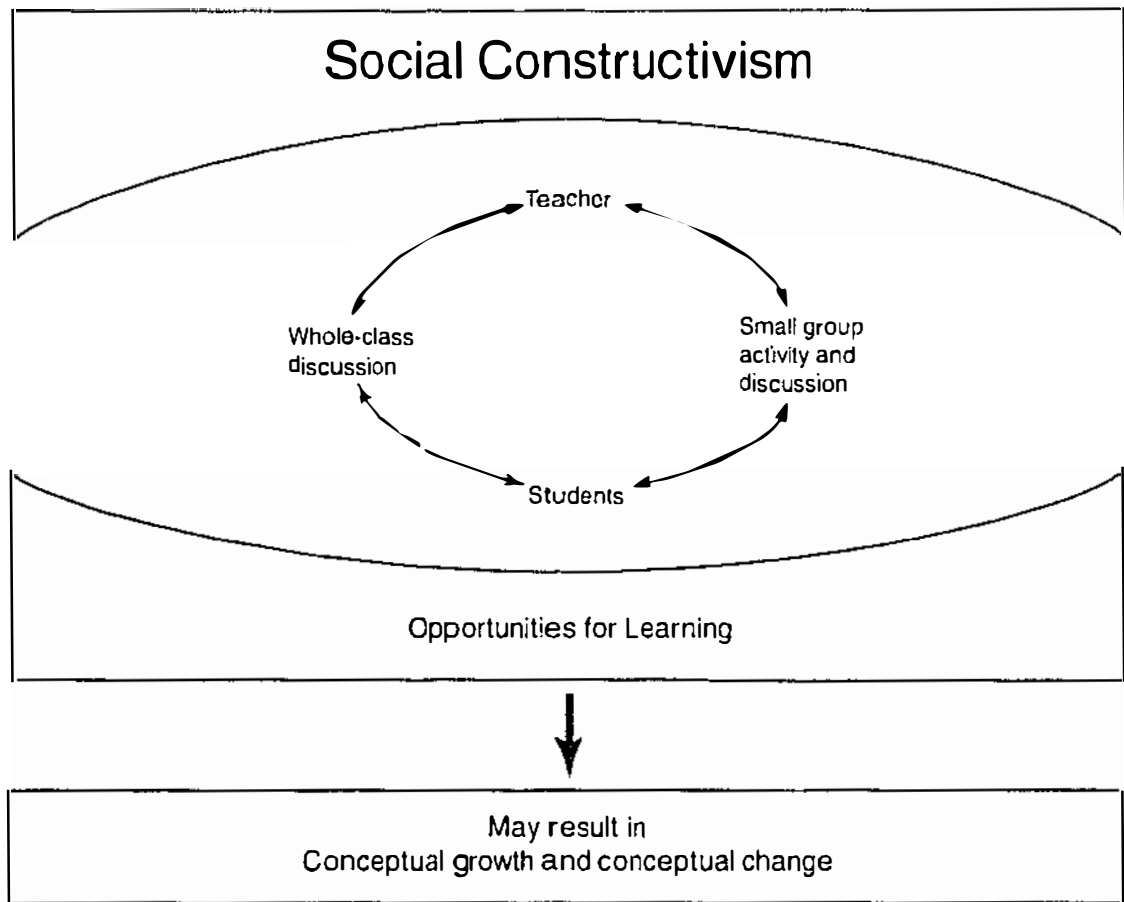


Figure 2.1 . Teaching and learning for conceptual growth and change

Teachers are able to pay closer attention to individual understandings when interacting with small groups of students and can ask questions and make statements that help to direct the small group discussion towards new understandings or new ways of testing their own or other's understandings. They can help manage the group processes and suggest ways that interpersonal problems may be addressed. At the same time, with the more informal situation in small group discussions, the students are able to offer ideas and suggestions and engage in discussion, conceptual or otherwise, with the teacher and the other group members. This allows the students time to consider their ideas and the teacher an opportunity to consider their understandings and plan new learning experiences which will develop better understandings.

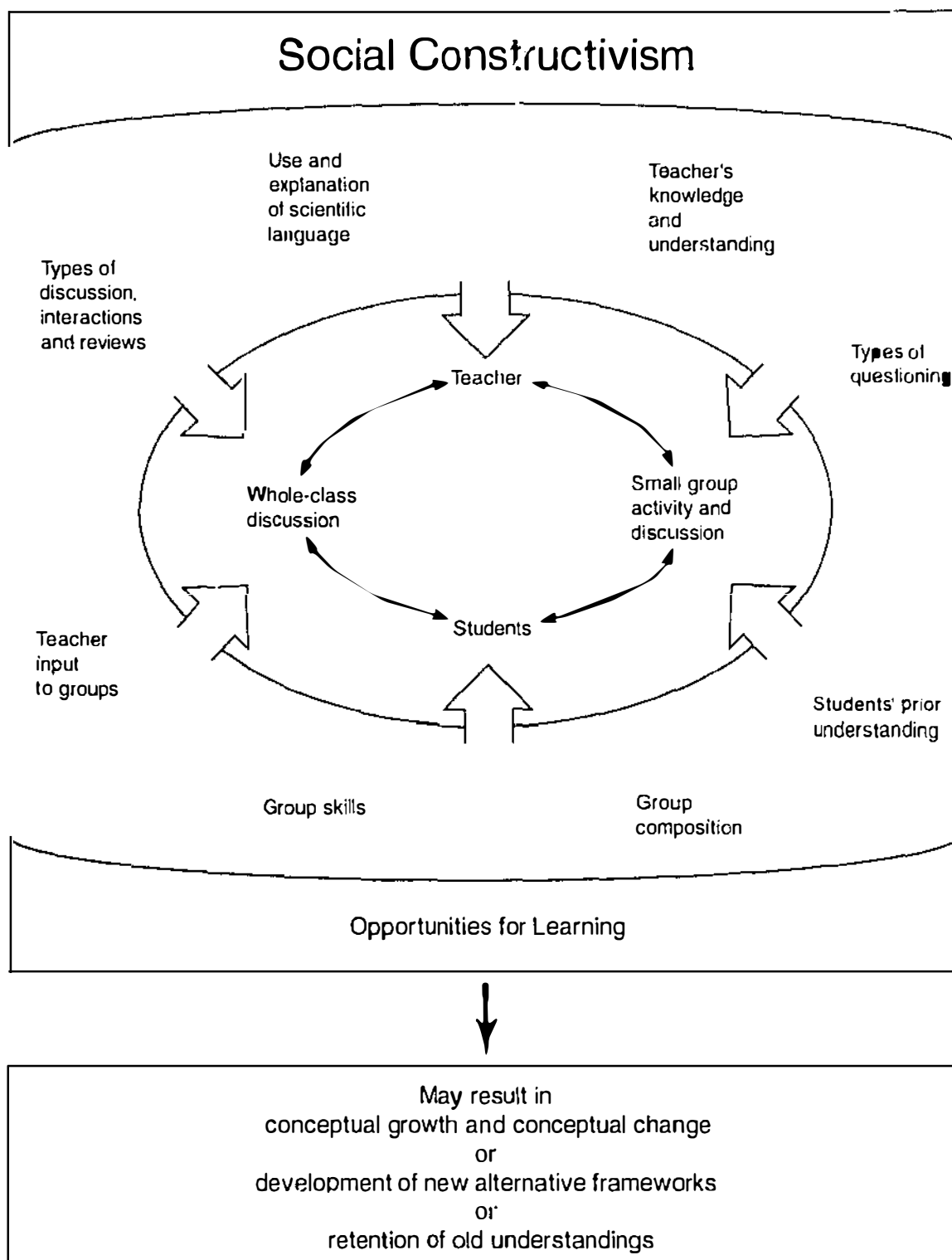


Figure 2.2. Teaching and learning for conceptual growth and change: Aspects that may affect learning

However, this chapter has indicated the range of situations that affect the opportunities for learning that are available in the science classroom and the understandings that students develop. These can be grouped under headings (figure 2.2) and summarise the effects that the classroom environment might have. These include: the level of constructivist teaching in the classroom; the types of discussion and questioning that occur, both in the classroom and in group work; the functionality of the

groups the students are working in; the teacher's level of knowledge and understanding about the science content, alternative frameworks and conceptual change teaching strategies; and the teacher's awareness of the likely problems with language in science lessons (Figure 2.2). All of these things can interact and can affect the quality of teaching and learning that occurs, with students retaining their old understandings, developing new incorrect understandings or moving towards a more scientific view of the topic under discussion.

The types of interactions in classrooms determine the opportunities for learning which allow the possibility of growth or change in the students' conceptual frameworks. The next chapter discusses the methodology of the study and the steps taken to ensure its rigour and the trustworthiness of the data gathered.

CHAPTER 3

Methodology

Introduction

The Researcher

Guba and Lincoln (1981) considered that it is important that information is available about the perceptions of the researcher and the effects that these might have on the study and Marshall and Rossman (1989) stated that any biases that the researcher might have need to be discussed. The researcher is a practicing primary teacher with 15 years teaching experience and an interest in teaching science and, as such, is aware of many of the problems and constraints that occur in primary classrooms. Immediately prior to this study she was a classroom teacher, but had previously taught science to students from Years 1 - 7. She is aware of the range of teaching that occurs in science and has seen good lessons but has also seen those where the science consisted of completion of worksheets or where the hands-on practical activities were completed with little understanding developed and no teacher-directed discussion. She is currently an upper-primary teacher who coordinates the science in the school and provides professional development on current practice for the teachers in the school.

She has an interest in alternative frameworks and her Honours thesis examined the understandings that Year 7 students had about light and sight. She has also co-written a paper on alternative frameworks in astronomy. During the initial years of this study she taught science education to undergraduate education students at university; provided professional development for teachers in a variety of fields, including science education; and continued teaching in primary schools through relief teaching. Once again, this gave her an insight into the types of science lessons that were being conducted in schools. The topic for this study was chosen because of the awareness of the range of teaching practice that was occurring and a recognition that there was much in science education about which teachers were unaware.

Observers bring to any study their own experiences (Erickson, 1986), ideas and judgements (Angrosino & Mays de Pérez, 2000). The researcher-observer needs to be impartial and a deliberate effort was made to limit any bias by recording factual observations and avoiding inferences and opinions. The researcher was only involved in

casual interactions with the students during the lessons and did not offer advice or suggestions to the teachers.

The Choice of Research Methods

Dane (1990) discussed the settings in which field research may occur and conceded that there are likely to be differences in the results of research carried out in laboratory type settings and more natural settings. Therefore, to examine the interactions and activities that occurred in primary science lessons it was necessary to conduct the investigation in working classrooms where the teacher was able to conduct the lessons in his/her usual way and the students were in their usual environment. It was decided to conduct an interpretive study (Erickson, 1985) which was similar in design to a case study or field work (Dane, 1990; Yin, 1984). However, in order that the lessons contained similarities, the lesson frameworks were supplied by the researcher. Dane (1990) states that "Events may be artificially created by the researcher and still be perceived as natural by the participant" (p. 147). The researcher attended each lesson as an observer and fitted Angrosino and Mays de Pérez (2000) description of an observer as participant which allows the observer to interact incidentally with the participants.

To provide a range of data for comparison, it was decided to look in three classes. Stake (1994) and Yin (1984) both considered that it is possible for researchers to study several cases in order to investigate the area of interest.

As suggested in qualitative research methodologies (Cobh & Hagemaster, 1987; Goetz & LeCompte, 1984; Marshall & Rossman, 1989), the literature review and conceptual framework provided information which led to the development of the research questions.

Participant Selection

Selection of Schools and Teachers

Stake (1994) considered that the selection of cases to study is most important and a representative sample is necessary. Because of the necessity for good interactive language to demonstrate the development of understanding, it was decided to use upper primary classes (11 and 12 yearolds) as the levels of language and discussion skills of the students were likely to be more advanced than those of younger students. To obtain a range of teaching styles one teacher was required to be knowledgeable about science, particularly of the topics chosen, one less knowledgeable and a further teacher was

required who could be in either category. The number of visits required to the schools meant that they needed to be within reasonable driving distance from the researcher's home. The Principals of schools within this area were contacted and two schools who were willing to participate in the study were chosen. The teacher at the first school was knowledgeable about the topic of electricity. The second school selected had two Year 7 teachers who were interested in the study and discussion with them indicated that their backgrounds differed from the first teacher and it was decided that, as both were interested, both classes would be included in the study although it was recognised that a further class might be necessary if their teaching was too similar. However, the two teachers were very different with different teaching styles and attitudes.

Selection of Students for Focus Groups

As it was not practical to monitor all group discussion in the classroom one group of students in each class, designated the Focus Group, was selected to be video recorded. Students for the Focus Groups were selected based on discussion with the teacher and the results from the pretest data. The teachers were asked to suggest students who would probably have some alternative science understandings but who would communicate and interact well together. The students' names were checked against the pretest to ensure a range of understandings.

Selection of Data Gathering Techniques

This study was designed to relate the conversation and interactions that occur in the classroom to the development of understandings. To obtain a wide range of information it was necessary to have access to the students' understandings prior to and after the unit of work; the teacher-class, teacher-student, teacher-group conversation; and the conversation that took place within the Focus Group. The Focus Group interactions in particular needed to be related to the context in which they occurred and it was possible that teacher interactions with the class or other students might also need to be related to context. Information was also needed from the teachers about their science knowledge and attitudes towards teaching together with general information about the school.

A pencil and paper test was used with the whole class to obtain data about student understandings, using the same test before and after the teaching. This provided basic data about the whole class but, being aware that student written answers might not

be as detailed as required, the students in the Focus Group were interviewed before and after the unit of work using the Interview-About-Instances technique (Gilbert, Watts & Osborne, 1981) to gain richer data about their understandings.

To ensure all the necessary contexts were available, the Focus Group was video recorded and the researcher attended all the lessons, recording events that occurred in the classroom together with any blackboard work, the general ambience in the classroom and any difficulties that occurred. Erickson (1986) discussed the use of audio and video recording and considered that it allows a more complete analysis of the data; avoids premature coding of instances; and allows the study of all events including rare occurrences. He also discussed some limitations: the researcher is unable to interact with the tape and contextual information is not available. Neither of these caused difficulties in this study because of the background information obtained and the presence of the researcher as an observer in the classroom.

To ensure breadth of data for analysis, several recording techniques were used. The teacher wore a lapel microphone to record all the teacher-class, teacher-group and teacher-student discussions. A second microphone was installed in the classroom and was used to assist in recording whole-class discussions. A video camera and connected microphone recorded the actions and conversations of the Focus Groups.

The Teachers and the Schools

Prior to the study, all three teachers were asked to complete a questionnaire (Appendix 1) to ascertain their teaching and academic background. They were also interviewed using a semi-structured interview format to provide information about their current class and school (Appendix 2). Informal discussions after the lessons were used to discuss any occurrences during the lesson to ensure that the researcher's interpretation of events was the same as that of the teacher. These discussions further developed the researcher's knowledge of teacher understandings and ideas and notes were made of the discussion prior to leaving the school. During the course of the study, new questions arose which were covered by a further semi-structured interview with each teacher after the study was completed, which also, again, allowed the researcher to check her interpretations of events. Validation of this type of data by the participants is important (Stake, 1994; Yin, 1984) and all the descriptive data related to the teachers, their classes and the schools was written-up and the report was forwarded to the teachers

for their validation. The responses provided further information which was incorporated into the thesis.

Lesson and Instrument Design

Ideally, when teaching from a constructivist perspective, the teacher discovers what the students know and then designs learning experiences that provide opportunities for conceptual growth (eg. Cosgrove & Osborne, 1985a, 1985b; Driver & Scott, 1996). The pretests provided this information but the teachers did not ask to see them or wish to use them as a basis for any of their teaching. The lessons had been designed expecting this, and provided learning experiences which would address the alternative frameworks that research indicated the students might have. These are detailed in Chapter 2. In each lesson the students are given an opportunity to suggest their ideas; test the ideas that they and others have suggested and discuss them in a small group situation; discuss their conceptions of what is happening and listen to others in whole-class discussions; and complete a theoretical activity based on the new understandings that had been developed.

Choice of Topic Area

Two sets of lessons were designed. To avoid the “novelty effect” (Gay, 1987, p. 276) affecting the study, one set was used so that students and teachers could adjust to the lesson format and become accustomed to the presence of audio-visual recording equipment in the classroom. The second set of lessons was used to provide the data required for the study. Topics from the physical sciences were chosen and, after discussion with science educators, the areas of light and electricity were chosen, with the electricity lessons used for the study. Both topics occurred in the Year 7 curriculum materials that were in use at the time (Western Australian Education Department, Curriculum Branch, 1976) and it was felt that the overlap between everyday and scientific language and knowledge in these two areas would enhance the study (Osborne et al., 1983; Sutton, 1980). Research has also indicated that electric current, although often covered in primary schools, is a topic which students may find difficult as many of the concepts are abstract and not observable (Arnold & Millar, 1987).

Development of Lessons

A literature review identified the areas within the topics where alternative understandings were likely to occur and the types of understandings that might occur

(eg. Arnold & Millar, 1987; Coulstock, 1991; Fetherstonhaugh, Happs & Treagust, 1987; Karrqvist & Anderson, 1983; Fredette & Lochhead, 1980). Those likely to occur in primary school children and which might be remediated through science teaching were selected and the frameworks for two series of lessons, one for light and one for electricity, addressing these were prepared. A further review of curriculum literature (eg. Queensland Department of Education, Curriculum Branch, 1983) identified activities that would be suitable or that could be adapted for Year 7 students, and ideas were also selected from the researcher's teaching experience. These were then collated into sequential teaching activities where knowledge was gradually built up over a period of four lessons for each topic area with a further application lesson which was not used by the teachers in the study. Focus questions were designed which directed the lesson discussion towards the propositions being developed and, using these focus questions as a guide, the background information for the teacher was written. For each lesson a worksheet, designated a Summary Sheet, was prepared, which was used to focus the concluding discussion of the group. A booklet was produced for each of the sets of lessons together with diagrams for classroom display (Appendix 3).

Kits of materials were organised to allow a class of 32 students sufficient equipment to work in groups of four students, with the equipment placed in boxes for ease of distribution. The teacher's kit contained the equipment for the demonstrations, extra equipment in case of loss or breakage and materials to replace consumables.

Development of Instruments

The evaluative instruments used in the study were the pre and posttests and the interview cards in both the topic areas, which were developed at the same time as the lessons.

A separate test was designed for each topic area to test all the propositions taught. As the test was required to examine understandings already identified it was decided that it should include pictures of instances (Gilbert et al., 1981) and not only ask the student for an answer but also why s/he chose that answer. Identical tests were used for pre and posttests (Appendix 4). A semi-structured interview outline was designed based on the pictures from the tests with one extra instance card added relating to globes in series and parallel. This was used for the Interview-About-Instance interviews (Appendix 5).

Validity and Reliability of the Lessons and Tests

The sets of lessons and tests were given to science educators to examine to ensure that the activities and language were at a suitable conceptual level for Year 7 students and the science content of the lessons was correct. The science educators confirmed that the test had good content validity and addressed the propositions developed in the lessons. The tests and interviews were also validated against the lessons by comparing test and interview questions to the lessons, the concepts taught during the lessons, and the focus questions.

Although the tests were administered by three different teachers, specific instructions were supplied in the lesson outlines to assist in ensuring the tests were conducted in a similar fashion.

To check test-retest reliability (Gay, 1987), one class was required to complete the posttest twice. Gay suggested that a week is a suitable time lapse between tests and Mr Avery was willing to allow his class to complete the test twice, with a week's break between tests. A Spearman Correlation Coefficient was conducted on the results with a coefficient of 0.92, indicating a highly satisfactory level of test-retest reliability.

All interviews were conducted by the researcher who had previous experience of this type of interviewing, and were audio recorded. Where students were required to select answers or indicate answers on the instance cards these were either recorded by the researcher during the interview, or the sheets on which the students wrote or made their choices were retained. The audio recordings were transcribed at a time as close to the interviews as possible to assist in interpreting any unclear speech.

Trialing of Lessons, Tests and Interview Cards

The lessons, tests and equipment were trialed in a Year 6/7 class in a semi-rural state school outside Perth. The teacher was an experienced primary school teacher and was in her third year of teaching science throughout the school. Her area of expertise was biology and she was aware that she was weaker in the physical sciences. After the lesson had been taught each week the teacher audio recorded a critique of the lesson and materials, which was collected each week and, where necessary, adjustments made to the materials. Regular visits were also made to the school to discuss the lessons and to assess the students' ability to complete the Summary Sheets.

The only major change suggested by the teacher was the inclusion of student instructional worksheets to eliminate the need to list all activities on the blackboard.

These were designed and included, with a note added to the lesson sets stating that the use of these was optional. These will be referred to as worksheets to avoid confusion with the Summary Sheets.

The tests were also used when the lessons were trialled. These were analysed and points of misunderstanding noted. Where it was apparent that the misunderstandings were common, the wording of the tests was adjusted to improve understanding. After the test feedback had been received from the trialing teacher, the interview cards were checked and adjustments in wording made as necessary. These were then trialed with 10 Year 7 students in a second school in a similar semi-rural area. No changes were found to be necessary.

Overview of Lessons

This section summarises the information that was in the lesson outlines provided to each teacher. It describes the general structure that was suggested for all lessons, the propositions and objectives for each lesson and the activities.

At the beginning of the curriculum package it was explained to teachers that the lessons were outlines and could be adapted or changed to suit their teaching style and students, but it was emphasised that the objectives needed to be met and the main points, indicated by the focus questions, needed to be covered. The teachers did change their presentations and this will be discussed within the descriptive data chapters.

Lesson Structure

Introduction

During this time teachers would be expected to introduce the topic, discuss the activities and distribute equipment and worksheets and, if necessary, organise the groups. It could also be used as an opportunity to review previous work.

Group work

Each lesson had a large component of activity work where students worked in groups of three or four. This could be split into separate activities with discussions after each activity. The students were either expected to follow the instructions on the worksheets or the instructions offered by the teacher. The worksheets provided points for discussion by the group members.

Whole-class discussions

These occurred at varying intervals within the lessons and were teacher led discussions of what the students had discovered and what they considered was happening. Focus questions were supplied to ensure the concept areas were covered.

Lesson Summary Sheets

These were designed to encourage the students to think about what they had learned during the lesson and were intended to take 10 - 15 minutes to discuss and complete. The Summary Sheet contained information about a situation which related to the activities covered in class. The students discussed this in their groups and then answered the questions on the sheet individually.

Lesson 1

The propositions listed for Lesson 1 were introduced in this lesson, but most were also implicit in the other lessons.

Propositions

1. If components have not been connected in a complete circuit there is no electric current in any component.
2. The amount of electric current in any part of a circuit will be the same.
3. Joins in a circuit consisting of wires, batteries and globes need to be at specific points on the batteries and globes to result in a working circuit.
4. When a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery.
5. Electric current travels in one direction through a circuit.

Activities

The students drew circuits which they considered would result in a lit light globe using one battery, one globe and one piece of wire. A selection of these were drawn on the blackboard and then students used the materials to construct and test the circuits. All circuits constructed were to be drawn on the worksheet, either as a working or non-working circuit. Students were asked to discuss the direction of the flow of current in the circuit as a group activity.

The second activity was similar to the first except students were asked to use two pieces of wire. Again they drew possible circuits first, a selection were drawn on the blackboard and then the students constructed and tested the circuits and discussed the direction of current flow.

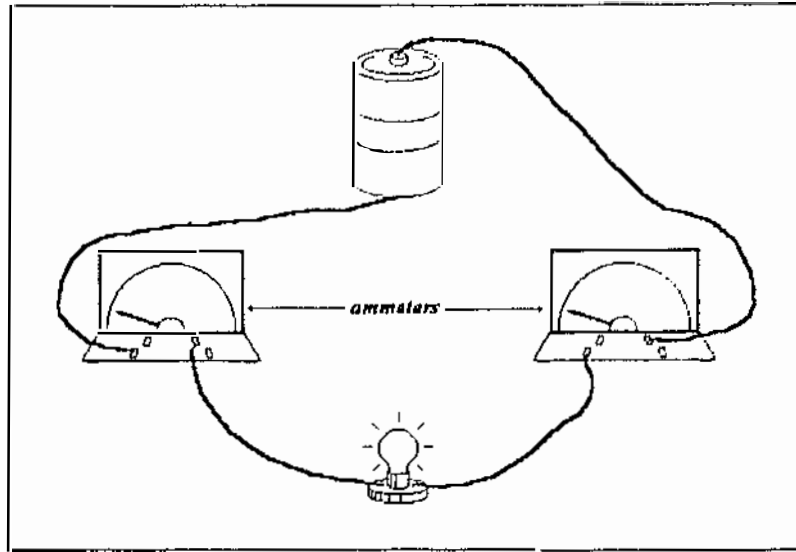


Figure 3.1. Circuit used to demonstrate the amount of electric current in the wires

The next activity was a whole-class demonstration where the teachers used ammeters to demonstrate the amount of electric current in the wires in a circuit (Figure 3.1), followed by a role-playing activity (Whitaker, 1993) where students role-played the components of the electric circuit just demonstrated by the teacher (Figure 3.2). The Summary Sheets, which asked the students why a circuit connected incorrectly would not work and how this would need to be changed to produce a working circuit, were then completed.

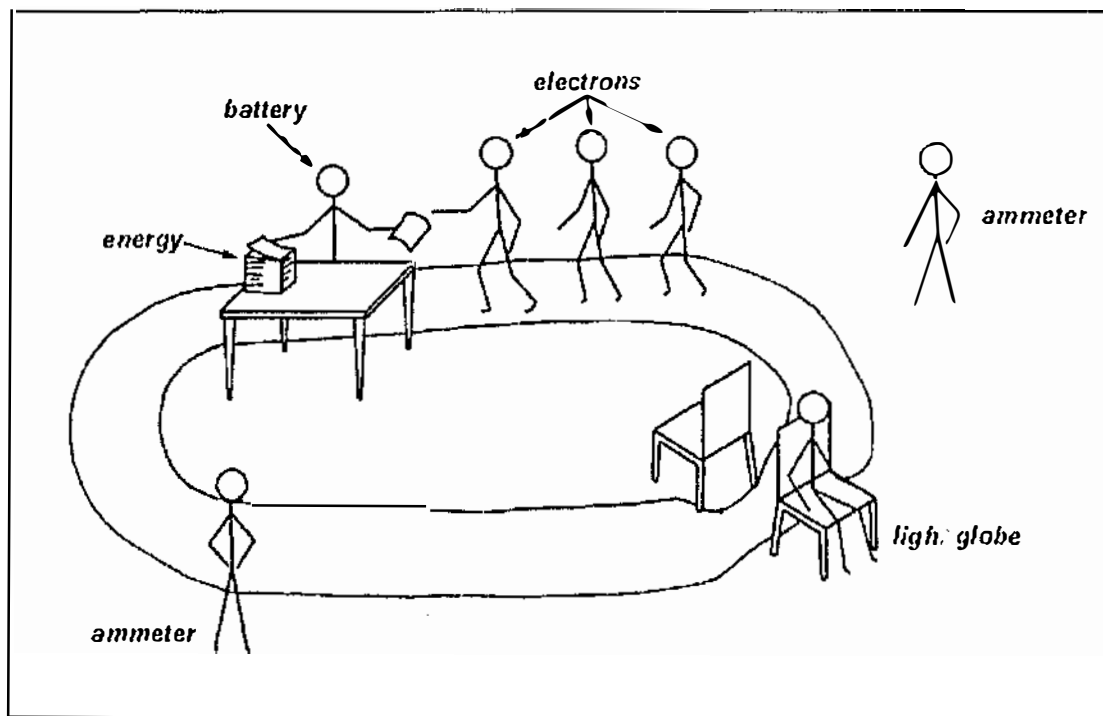


Figure 3.2. Format of role-play activity

Lesson 2

Propositions

- 6. Some materials allow electricity to flow through them.
- 7b. If the total voltage of the batteries is less than the voltage rating of the globe, the globe will be very dim.

Activities

The students initially constructed a circuit the same as that produced in Lesson 1, but included an extra wire in one side of the circuit (Figure 3.3). During this lesson, for ease of construction, they were allowed to use globe holders and wires with alligator clips at the ends. The worksheets then asked them to compare this circuit with that of the previous week and decide whether they were the same. The two joined wires were unclipped and connected to two drawing pins inserted into a piece of polystyrene foam and which touched each other. They were asked to look at what happened and discuss why it was happening. They then separated the two drawing pins (Figure 3.3) and, again, observed and discussed what happened and drew the circuit they had made.

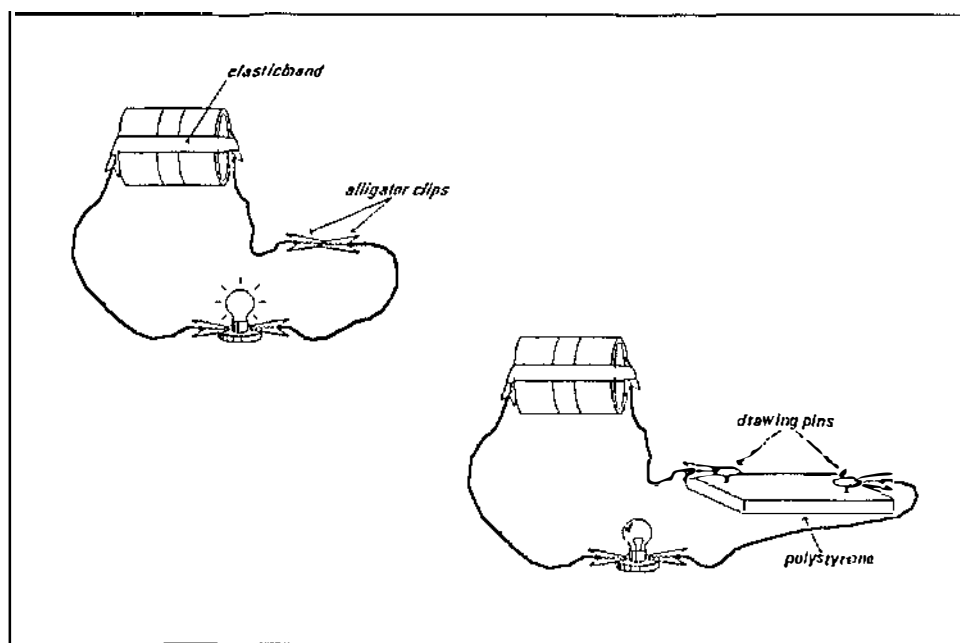


Figure 3.3. Circuits constructed by students in Lesson 2

The next activity asked students to attempt to reconnect the circuit using a variety of materials that had been supplied by placing them between the two drawing pins. They were asked to sort the items into materials that reconnected the circuit and

those that did not and list them on the worksheets. They then used one of the sorted materials to make and incorporate a switch into their circuit.

Lastly, the students constructed a simple circuit using two wires and a 1.3 volt globe. They recorded the brightness of the globe and then changed it for a 2.6 volt globe and then a 4.8 volt globe, recording the brightness of the globe each time. Again, the worksheet asked them to discuss what was happening and why.

Teachers then connected ammeters into a circuit which was the same as that used for the first activity, to demonstrate that current no longer flowed when the circuit was not connected.

The Summary Sheets, which asked the students to explain why a switch made out of an insulating material would not allow a circuit to work and to suggest a more suitable material, were then completed.

Lesson 3

Propositions

- 7a. When several batteries are connected in series, current flow will be greater than with a single battery
- 7b. If the total voltage of the batteries is greater than the voltage rating of the globe, the globe may blow; if it is less the globe will be very dim.
- 7c. When several globes are connected in series the voltage available is divided amongst the globes and the globes appear dimmer than if connected in parallel.

Activities

Initially the students constructed a circuit using two pieces of wire, a battery and a 1.3 volt globe. They then replaced the 1.3 volt globe with a 4.8 volt globe and were challenged to add one and then two extra batteries into the circuit in a way that would make the globe shine brighter. They needed to draw all the circuits they made, showing circuits which improved or did not improve the brightness of the globe, and were asked to discuss what happened and why. They then predicted what would happen if they removed a battery from the circuit and tested their prediction. Again they were required to discuss the results.

For the second activity, the students made a simple circuit as at the beginning of the first activity, but leaving the 1.3 volt globe connected. They were asked to predict what would happen if they added extra globes to the circuit and were told to add the globes by disconnecting one alligator clip from the globe holder and connecting in the

second and third globes. They were asked to discuss what was happening and why. They then predicted what would happen if a globe was removed from the circuit and tested their prediction, again discussing the results.

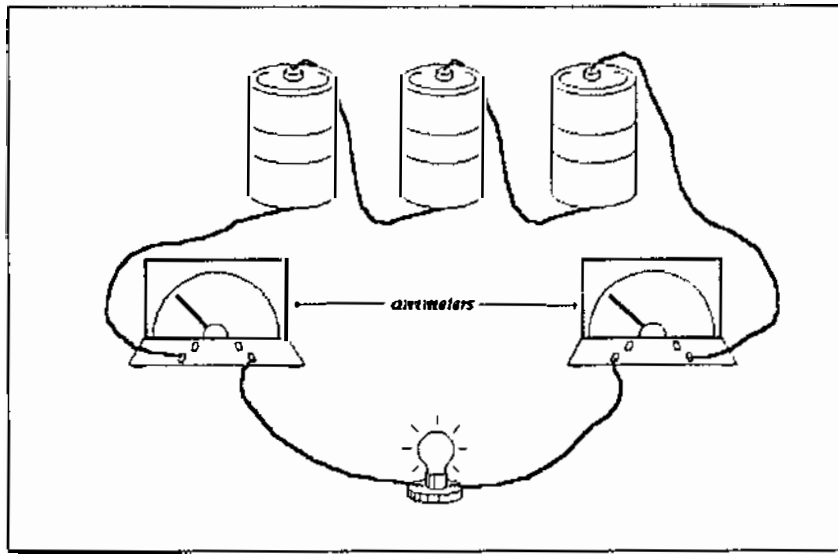


Figure 3.4. Circuit used to demonstrate current flow in series circuits

The teachers then demonstrated the increase in current flow using a series circuit incorporating three batteries and ammeters (Figure 3.4).

In the last demonstration the teachers connected a 1.3 volt globe into a series circuit using three batteries to demonstrate that, when a 1.3 volt globe is connected to 4.5 volts of electric current, the globe will blow.

The Summary Sheets, which asked students why a circuit with a 1.5 volt battery and a 4.5 volt globe was not producing a bright light, and then asked them to suggest a way of producing the required brightness, were then completed.

Lesson 4

Propositions

- 8a. When several batteries are connected in parallel, current flow is the same as that for a single battery and the current will operate for longer than when the batteries are connected in series.
- 8b. When several globes are connected in parallel the voltage is applied equally to all the globes and they appear brighter than if connected in series.

Activities

The first activity was a whole-class investigation which was set up shortly before the commencement of the lesson. This consisted of a simple circuit using one AA

battery, and series and parallel circuits each using two AA batteries. This was explained and discussed and then left on during the lesson with the students and teachers watching the relative brightness of the globes to ascertain which circuit lasted longest (Figure 3.5).

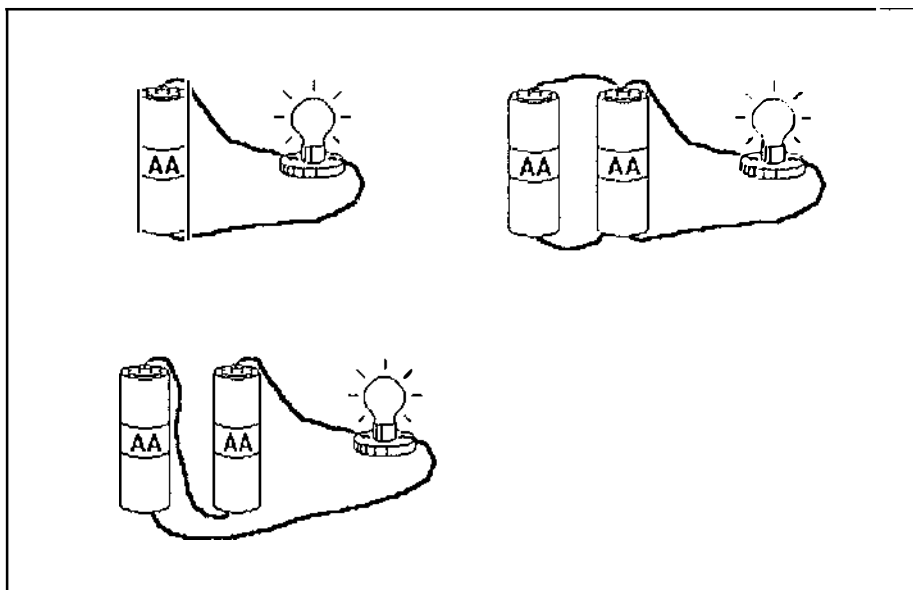


Figure 3.5. Circuits used in the whole-class investigation

In the first group activity the students constructed a simple circuit using two wires, a battery and a globe. They were then challenged to incorporate extra globes into the circuit without disconnecting any part of the initial circuit. They needed to relate this to the globes in series circuit that they constructed in Lesson 3 and discuss why the results were different. They predicted what would happen if they removed any one of the globes from the circuit and then tested their prediction. Again they were required to relate this to Lesson 3's activity and discuss the differences and why.

In the second activity students removed the two extra globes from the circuit and then added in extra batteries without disconnecting any part of the remaining circuit. Again, this was to be related to Lesson 3's activity and the differences discussed. The students then predicted what would happen if one of the batteries was removed from the circuit, tested their prediction and discussed the results.

The teachers demonstrated the amount of current flow through a parallel circuit using a parallel circuit incorporating the ammeters and related this to series circuits.

The Summary Sheets, which asked the students to explain why a circuit with batteries connected in series would not continue working for long and to suggest a way

the circuit could be connected to make it work for a longer period of time, were then completed.

Lesson 5

There was a fifth lesson in the series where the students applied the understandings they had developed to construct a set of street lights for an imaginary model town. The lights needed to be on one side of the street; they needed an on/off switch; they needed to continue working if one globe was removed and they needed to continue working for as long as possible. None of the teachers included this lesson.

Data Collection and Analysis

There has been some discussion in the past about mixing quantitative and qualitative data within the research methodologies. However, it appears that using both types of data within a study is acceptable and Dzurec and Abraham (1993) stated that:

The traditional dichotomy between quantitative and qualitative methods ... is evolving towards a more neutral distinction, facilitative of the integration of methods. (p. 74)

Lincoln and Guba (2000) state that as early as 1985 they considered that qualitative and quantitative data were able to be used together. However, they emphasise that the use of both types of data needs to be conducted with care. Patton (1987) also discussed combining qualitative and quantitative data and suggests ways in which the data could be used although none fit the present study. He, again, emphasises the need for care in mixing data analysis.

Because of the nature of this study, both qualitative and quantitative analyses have been used. The interactions and activities in the lessons have been analysed both quantitatively and qualitatively, with statistics presented comparing time and numbers of utterances but with descriptions and examples of the discourse and behaviours that occurred. The test data and changes in understandings have also been quantified but, again, there are examples from the students' responses in the tests and interviews.

Testing

Pretests and posttests

The pretests and posttests were administered by the teacher and instructions were included to ensure that similar circumstances were adhered to for each test and class. It was administered to the whole class shortly before and after instruction so that

changes in students' conceptions could be identified and described. Where students were absent for either of these tests their data were not included in any analyses. It was not possible to administer a delayed posttest as the students were at the end of their last year at primary school and moved on to a range of high schools.

Interview-About-Instance Interviews

The Focus Group students were interviewed individually prior to and after the unit of work using Interview-About-Instance cards (Appendix 5). The interviews were audio recorded and transcribed shortly after the interviews, with these data used to extend the researcher's knowledge of the students' understandings.

Analysis of Data from Testing

Pretests and posttests

The pretests and posttests were used to produce an analysis of each student's understandings prior to and after instruction with the pretest data also being used to help identify members for the Focus Group. Data from the pretests were analysed to establish the types of understandings the students held. These were later compared to the posttest data to ascertain the number of students in each class who had changed understandings and the types of change that had occurred. Where students had made a scientific choice in their answer, their explanation was scored to show the level of understanding, with zero indicating no real understanding although they had made a correct choice, and three indicating an understanding that was close to the scientific view.

Video and Audio Recordings

Video recordings of Focus Group interactions

The video recording of Focus Group interactions was viewed immediately after the lesson and a journal kept to record initial reactions and items of interest such as moments of confusion or discussion about results. These episodes were analysed to ascertain the way the interactions took place and the apparent effect of the episode on the learning process. The researcher's interpretation of these events was recorded. Possible effects of these events were then looked for in the next lesson together with any other critical episodes. The language interactions from each video recording were transcribed by the researcher and contextual information from the video and classroom observations was added (Appendix 7). At the conclusion of the unit of work on electricity the Focus Group students were involved in a discussion with the researcher

where extracts from the videos were shown and discussed with the students' ideas and interpretations used to validate or extend the researcher's understandings.

Audio recordings of teacher-group and teacher-whole-class interactions

The audio tapes from the classroom microphone and the teacher lapel microphone were transcribed as one transcript, giving a record of the teacher's interactions with individuals, groups, and the whole class. Any long utterances were split either where the type of comment changed, for example, where the teacher's comments changed from conceptual discussion to managing the classroom behaviour, or where the topic under discussion changed. This is similar to Kempa and Ayob's (1991) description of utterances:

“... any verbal unit which possesses a recognisable and interpretable element of communicated information’. Thus utterances could consist of simple phrases or sentences (incomplete sentences), complete sentences or even chains of phrases or sentences ...” (p. 345)

The observational data were added to this transcript (Appendix 7).

Analysis of Data Contained in Transcriptions

All the transcript data were transferred to a computer database with a separate database for each lesson, separated between the whole-class/teacher-group data and the Focus Group data. This was then coded to supply information about the type of activity that was occurring; the types of interactions that occurred (eg. feedback, instructions, suggestions); use of media or models (eg. blackboard work, use of built circuits); and the concept areas that were covered. The categories chosen were specific and objective in order to minimise coding difficulties (Dane, 1990) The coding evolved as the study progressed, with the transcripts and recordings re-examined and reinterpreted as new information was generated, a strategy which Stake (1994) considers is essential in case study research. The database was used to generate information about the types of interactions and behaviours of the teachers, the class members and the Focus Groups. It provided information about the number and types of interactions that occurred for concept areas; the amount of conceptual discussion that occurred; comparisons between the amount of and type of teacher speech and student speech; the types of strategies used by teachers and students; and contextual information. Because the information offered by the teacher to each individual group usually differed, the content of the teacher-group transcriptions was not included in the analyses. However, it was used

when comparing the information given by teachers to the whole class with that given to individuals or small groups.

Students' Written Work

Any written work, including the supplied worksheets and the Summary Sheets, that was completed by the students was collected and retained. These were analysed to ascertain the understandings that students had at various stages of the lessons and were used for reference when unusual changes occurred in individual student understandings.

Collation and Analysis of Data

Data validation in qualitative research is usually by means of triangulation (Erickson, 1986; Miles & Huberman, 1994; Patton, 1987). Miles and Huberman listed Denzin's (1978) four types of triangulation; data source, method, researcher and theory, to which they add a fifth, data type. This study uses a variety of data sources, methods and data types, within and across classrooms.

Data analysis in qualitative studies involves the researcher in looking for patterns and links across the data generated. Miles and Huberman (1994) suggested that pattern finding is useful when there is a large amount of data to be sorted and feel that this method can reduce the data to a manageable number of 'propositions'. They also offer clustering as a method of sorting data, where connecting links are looked for between information. These clusters can overlap with links made between clusters. Erickson (1986) suggested the generation of assertions from the data which can then be linked to provide general assertions. Both clustering and the generation of assertions are similar and either could describe the data analysis used in this study, although Erickson's terminology has been used.

As each aspect of the lessons was discussed and described, assertions were developed which were based in occurrences in the classrooms. For some assertions, only data from two classrooms were used, and in others data from one of the classrooms indicated that, by not engaging in the behaviours of the assertion, the opposite of the assertion occurred. The assertions were reframed as more evidentiary data were found and evolved as the analysis progressed as suggested by Erickson (1986). These assertions were then clustered to produce general assertions producing a statement linking together these ideas and, again, the evolution of both the assertions and the general assertions was on-going. The general assertions were then linked together to

produce overarching assertions resulting in general statements which summarised the findings of the study.

Research Consistency

In this type of study it is difficult to avoid the research affecting classroom life. The teachers may have changed their teaching style to what they felt was expected, but the students did not appear concerned about the research, usually ignoring the recording equipment as was indicated by much of their off-task conversation. The research consistency was maintained by all data collection including observations, interviewing and transcribing, and all coding and scoring being completed by the researcher with samples of the coding and the scoring criteria checked by science educators.

Confidentiality/Ethics

Christians (2000) stated that all participants in a study must be fully informed about the study. The teachers were informed verbally of the intentions of the study at a meeting and were sent a letter summarising the information. They all signed forms indicating that they were aware of the focus of the study and were willing to participate. A letter containing the information about the study was also sent to the parents of all students, together a permission form for the parents to sign. All these were returned completed.

Christians (2000) also stated that researchers must protect the identity of the participants and the locations, although he conceded that insiders may still recognise individuals. Confidentiality has been maintained by only the researcher and her immediate supervisors having access to the video recordings and other raw data that may identify the participants. All the audio and video tapes are locked away and will be destroyed after five years. Each school, teacher and student within the study was given an identifying code or name which was used in all transcripts and in all written work. Any descriptions given in the thesis give sufficient data to identify the type of school, teacher or student but give no information which may lead to the actual identification of any of these.

The next chapter, Chapter 4, gives an overview of the schools and teachers involved in the study as an introduction to the descriptive chapters which discuss teaching and learning in the classes.

CHAPTER 4

Overview of Teachers and Schools Involved in the Study

Introduction

In the remaining chapters, the text includes quotations from tests, interviews and lessons. A code is used to indicate the student concerned, eg. 1F20. The first number of the code indicates the class, the next letter indicates student gender (M = male, F = female) and the final number is the number given by the researcher to the student. Where teacher or student names are shown these are pseudonyms. The test quotations are written as the students wrote them on the test sheets and may include spelling and grammatical errors.

This Chapter describes schools in which the case studies were conducted and the teachers who were involved. There were three teachers, Mr Avery, Ms Brown and Mr Carter, with Ms Brown and Mr Carter teaching at the same school.

The First School

The first school was situated on the outskirts of Perth. Most of the school buildings were the older linear style of building with single width blocks of classrooms, although there were some new additions. There were about 280 students in the school. The staff were all experienced and most had been at the school for some years resulting in a stable environment.

Mr Avery was the science coordinator and did not consider that science was well taught in the school, stating that there was only one teacher who he knew taught it on a regular basis. He said that the school was well equipped for science but that the equipment was not used. He asked the teachers at the beginning of each term if they required anything for science and was rarely asked to buy anything. Mr Avery took science in both the Year 7 and the Year 6/7 classes and ran the same programs in both.

Mr Avery and his Class

The Class

This class was a mixed group of Year 6/7 students with all the students in the Focus Group being Year 7 students. There were 15 girls and 13 boys in the class, all having stable home environments with only one being from a single parent family. There were no students who had a home language other than English.

Student characteristics

Mr Avery considered that the students interacted well socially and this was demonstrated by their cooperative work within the groups. However, there were a few instances of individuals dominating the activity work during the series of lessons.

Mr Avery considered most of the students were good at following both written and verbal instructions with six or seven needing to be redirected. Group work was used in all curriculum areas with group sizes from two to seven depending on the type of work. The group conversations were often animated and enthusiastic.

The students were allowed to take responsibility for tasks beyond normal classwork. After the unit was over the students were given a home project building a model incorporating an electric circuit which was then video recorded by the students with little supervision.

Composition of groups

Mr Avery did not insist that students stayed in the same group each week although the groups often stayed the same or similar, either because they were friendship groups or because students were sitting at adjacent desks. The Focus Group remained the same throughout the lessons.

Students' academic ability

Shortly after the lessons were finished Mr Avery was asked to rate the students' academic ability on a scale of one to five where one was very high and five very low. Students from this class were generally able with no students at level five, and five given a rating of four. Eight students were at level three, and six at each of levels two and one.

The Classroom Environment

The class was in an air-conditioned transportable classroom resulting in a high noise level during activity lessons. The classroom always had displays of students' work on the walls which were regularly updated and much of the work was not the usual Year 7 work, suggesting that the teacher was innovative.

Mr Avery

Academic background and teaching experience

Mr Avery had taught in several state primary schools over a period of 19 years, 12 of which had been in Year 7 classrooms. He studied physics and chemistry in Year 11 and 12 at high school and included in his pre-service teacher training elective units in science, art and physical education. When he was working on his Bachelor of Education

degree he took a further four units in science, two each in mathematics and education and one in art and had since attended a variety of science in-service courses. He spent one year seconded as a lecturer in primary science education at a teacher training college and was also part of a team that wrote a curriculum package for Year 5 - 8 Technology.

Science knowledge

Mr Avery was very knowledgeable about the topic of electricity and taught it most years. He was not only able to address the propositions that were included in the lesson guidelines but was also able to address other related incidents that occurred within the lessons. He was also aware of the difficulties which were likely to arise from students' idiosyncratic ideas about phenomena.

Philosophy

Mr Avery felt science was as important as all the other subjects taught in primary school. He considered that students often know a considerable amount about a science topic before they come to the classroom:

Researcher *How do you think the kids in your class develop their actual science understandings?*

Mr Avery *Um, yeah, a lot of the time it's what they already know.*

He felt that students develop understandings by doing activities and focusing on specific discoveries. He believed that teachers need to direct the learning by discussing the activity and alternative ways of approaching the investigations, and to then focus on the important concepts, with the teacher providing examples and the students recording a short reminder:

Mr Avery *... and then the other thing is actually doing and then focussing on specific discoveries like lighting up a globe uh, and so on. Then someone turns it around you know and changes the direction of the wires and says look at this one, and then you say look can you do it some other way? And then you focus in on the important concepts then.*

Researcher *And how do you actually focus in on it apart from the activities.*

Mr Avery *Well, we talk about it, talk about it and then provide them with some dramatic representation show them some models and things of how it works get a visual * get down to actually recording. They can just copy down a sentence like yesterday, just to reinforce that and so we've got a got a lot of discussion.*

N.B. Asterisks (*) are used throughout this thesis to indicate that a word was inaudible on the audio-tape.

Mr Avery believed that science activities needed to be challenging to maintain student interest and he considered that his students enjoyed science as there was less

“academic pressure” on them and they could be noisier. He felt students tended not to discuss things unless they were specifically told to do so and, unless the discussion was structured, students would only stay on-task for a limited time:

Mr Avery When you ask them to discuss something you've really got to set your focus questions. You've got to give them clear questions to answer and then they will. But if you say okay you've just done this, go and discuss what you've found or what have you just done? Discuss it. They're too open, too broad a question and therefore they really don't know what you really want ...

Science Topics and Lessons

Science topics

Mr Avery mainly taught the physical sciences, although he included biological topics to maintain a balance in his program. He also looked at the impact of science on society and incorporated consumer science and values education within science lessons.

Lesson structure

Mr Avery had two science lessons a week in each of the classes he was teaching, one of one hour which usually contained the practical activities, and a second of 30 minutes which was usually a class discussion and write-up. The one hour lessons during this study tended to be less than an hour and the second lesson did not always eventuate. When this happened, more time for discussion was organised during the main lesson. Mr Avery did not always use the formal method of writing-up experiments but would sometimes ask students to write brief notes or individual sentences as a record of the activity. His usual science lessons consisted of an introduction to the activity and then a description of the set task, with the students then working in small groups on the task before a class discussion. They then did an extension activity and some writing. During the follow-up lesson, usually the following day, he reviewed the work using discussion and questioning and the students were sometimes asked to write a formal report of the activity using aim, method, results and conclusions.

Mr Avery's Approach to Teaching the Electricity Topic

Prior to the series of electricity lessons Mr Avery taught four of the supplied lessons on light.

Use of Class Time During Electricity Lessons

The total teaching time for the electricity lessons was six hours 5 minutes. Forty-two percent of class time was used for group work including hands-on activities and

within-group talk about the activities. A further 33% of class time was used for whole-class discussions and 24% was used for class and task management. Interruptions to the lesson took up 1% of the total time.

Mr Avery did not teach the electricity lessons as they were suggested but spread them over a longer period. The lessons have been numbered to link to the lessons described in Chapter 3. Where one lesson was split into two, the first lesson has been given an 'a' suffix, and the second a 'b' suffix. Mr Avery combined parts of Lessons 3 and 4 to make a joining lesson and this has been given the number 3/4.

Lesson 1: Circuit Construction, Current and Current Flow

Mr Avery used two periods for these topics, one of 50 minutes (Lesson 1a) and a follow-up discussion and writing lesson of 25 minutes (Lesson 1b). He drew circuits on the blackboard for the first activity and students constructed and tested these rather than developing their own. He did not give them time to draw circuits first although they did draw diagrams of the circuits they made. He followed the other group activities as they were in the lesson, holding a whole-class discussion after each activity. The ammeter demonstration, used to show that the amount of current in any part of the circuit was the same, was extended by Mr Avery. Initially he demonstrated the amount of current in each side of the circuit was the same. He then reversed the battery in the circuit so that both the ammeters' hands moved below zero and used this to explain that the current was flowing 'backwards' leading to the concept of current flowing from negative to positive. To assist the group discussion at the end of Lesson 1a, he photocopied the focus questions and gave them to the groups to discuss and answer. He then conducted a whole-class discussion using the focus questions and ascertaining some of the student understandings, although lack of time prevented all the questions being discussed. The role-playing activity simulating the flow of current in a circuit and the Summary Sheet discussion were included in Lesson 1b, as was a comprehensive review.

Lesson 2: Conductors and Insulators

Mr Avery told the students to work through the worksheet which asked them to construct a circuit suitable for testing materials for conductivity and then test the supplied materials. However, the students either stopped after the first section or went off at a tangent and he spent some time bringing them back on task. Although the activity testing conductors and insulators was completed, the construction of a switch was omitted. There was little whole-class discussion during the lesson with a limited amount in the review section at the end of the lesson. Mr Avery started to use the

Summary Sheet as a discussion focus but the end of day siren sounded and the discussion was cut short with little conceptual understanding demonstrated. The final activity, testing different voltage globes with a 1.5 volt battery, was completed in Lesson 3. The Summary Sheet was not completed by the class, although the Focus Group completed it later.

Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages

Mr Avery spread the activities in Lessons 3 and 4 over three 45-minute periods and a discussion period (Lessons 3, 3/4a, 3/4b and 4) with parts of both Lesson 3 and Lesson 4 being included in Lesson 3/4. Lesson 3 started with a review of the previous lessons. The students completed the final activity from Lesson 2, with Mr Avery using three circuits constructed by the Focus Group to demonstrate the change in globe brightness when different voltage globes were used with a 1.5 volt battery. After constructing and testing circuits using batteries in series, selected students were asked to draw circuits on the blackboard. There was a diversion during the lesson when some of the 4.8 volt globes started flashing and the reason for this became a discussion and learning point. There were frequent discussions during the lesson and Mr Avery went through some of the focus questions but the end of school siren interrupted and the discussion was unfinished. No ammeter demonstration was used.

The second activity, connecting globes in series, was started by students towards the end of Lesson 3/4a but most groups did not complete the circuit. Mr Avery called the students to the front of the classroom and demonstrated the circuit and what happened when a globe was removed.

Mr Avery did not demonstrate the effect of connecting a 1.3 volt globe to three 1.5 volt batteries in series, but mentioned briefly during a whole-class discussion that the globe would blow. The Summary Sheet for Lesson 3 was completed at the beginning of the Lesson 4.

Lesson 4: Parallel Circuits

During Lesson 3/4a the whole-class investigation, which demonstrated the difference in the length of time a globe would continue functioning in simple, series and parallel circuits, was set up using D size batteries instead of AA. As nothing had happened at the end of the lesson the circuits were disconnected and reconnected the following day. This continued until after the series of lessons was finished and any discussion occurred outside of the recorded lessons.

The first group activity in Lesson 3/4a was constructing a circuit with globes in parallel, with one group coming to the front of the class to demonstrate their circuit and Mr Avery talking about the circuit. The groups were then asked to construct a circuit containing globes in series as this had not been done previously. Mr Avery then demonstrated the attributes of globes in series circuits and conducted an in-depth discussion of parallel and series circuits.

During Lesson 3/4b the differences between parallel and series circuits were reviewed and Mr Avery constructed a circuit with globes in parallel to reinforce the concept that globes could be connected so they shine with equal brightness.

During Lesson 4 Mr Avery initially discussed conductors and insulators, and the students were then asked to complete the Summary Sheet from Lesson 3 with no group discussion. The students then completed the second activity from Lesson 4, constructing a circuit with batteries in parallel. Rather than use the worksheet, Mr Avery gave verbal instructions to the class and only two groups succeeded in constructing the circuit incorporating two batteries. The other students were called to these desks to look at them and Mr Avery incorporated ammeters into one of the circuits. The activity was intended to demonstrate the current flow from each of the batteries but was confusing as the ammeters appeared to have differing readings and the students were reading different numbers from the dials. The students then returned to their groups to construct their parallel circuits. Mr Avery used one of the constructed parallel circuits to demonstrate removing batteries from the circuit and changing the 1.3 volt globe for a 4.8 volt globe and then reviewed circuits with batteries in parallel. The Summary Sheet for this lesson was not completed by the class although the students in the Focus Group completed it after the series of lessons.

Extra Lesson

Mr Avery added an extra lesson at the end of the series which involved the students in following written instructions to make what was termed a 'nerve tester', which tested the steadiness of the user's hands. This lesson, although related to the topic, was designed as a technology lesson (design, make, appraise) and there was little science or conceptual discussion.

The Second School

The second school was situated in a semi-rural area close to Perth. Most of the school buildings consisted of the older linear style of buildings with single width blocks

of classrooms around a quadrangle. The junior primary block and library were quite new, and there was a new utilities room where the science lessons were held. The school had 398 pupils. The teachers involved in the study were Ms Brown and Mr Carter, both experienced Year 7 teachers.

Neither teacher was sure about the amount of science taught in the school. Ms Brown considered that "quite a bit" was taught in junior primary and thought that some teachers set some science as a home task. Mr Carter felt that science teaching in the school had deteriorated since the time when he worked as a support teacher in science, possibly because of difficulties getting materials, but also because of teacher attitudes and time constraints. Both Ms Brown and Mr Carter stated that the science equipment in the school was limited. Ms Brown also commented that the Western Australian Science Syllabus and supporting materials were inadequate, but the school had purchased extra resource materials.

Both classes went to the utilities room for their science lessons. The students from Ms Brown's class were required to move desks and chairs into the utilities room prior to the lessons and those from Mr Carter's class returned them to the classroom. The students became very competent at organising the desks and settling reasonably quickly when they arrived. Copies of the supplied posters were displayed in this room as well as the classroom.

Ms Brown and her Class

The Class

This class consisted of 32 Year 7 students, 15 boys and 17 girls. There were no members of the class that had a home language other than English, and only two of the students were born outside Australia.

Student characteristics

Ms Brown considered the class was not good at cooperating with each other, and had several academically able students who liked to dominate and were strong willed:

Ms Brown They're very strong willed people. That tends to make it a little bit little difficult at times. ... They're great among their own close little group but from the wider perspective some of them do have difficulty coping. thinking about other people.

After the lessons, Ms Brown said that the groups may have worked better if they had been same gender groups.

*Ms Brown I think it would have probably been better if I'd had groups of girls rather than try and mix them because you find that they * off anyhow the boys 'll do their bit and the girls 'll do their bit. Otherwise the boys 'll commandeered the gear and the girls will sit back and watch. Unless of course you get one girl who is fairly pushy and dominant.*

Ms Brown felt that, with the range of abilities in her class, the students would find it difficult to follow written instructions and the instructions were always read aloud. She conceded that students varied in their willingness to follow instructions but felt that her class were quite good at it.

Ms Brown considered that some students were able to work independently and cited examples of students helping in the junior primary classrooms. The class had also been involved in a buddy scheme with Year 2 students which was designed to develop higher levels of responsibility. There was little individual responsibility demonstrated in the science lessons.

Composition of groups

Ms Brown organised the students into groups prior to the series of lessons, with most groups consisting of two boys and two girls. The groups remained the same apart from student absences.

Students' academic ability

Ms Brown stated that she had a group of about eight very academically able students, but also had two students who were working at a level very much below Year 7. Shortly after the study, when asked to rate her students' academic ability on a scale of one to five, where one was very high and five very low, two students were level 5, six level 4 and one 3/4. Eleven students rated at level 3, seven students at one and a further five at 1/2.

The Classroom Environment

The lessons were taken in a room where talk tended to echo and the noise level seemed high because of this. This was alleviated somewhat by the addition of fabric drapes and screens but it was never fully satisfactory.

Ms Brown

Academic background and teaching experience

Ms Brown had been a primary teacher for 19 years. She had also taught for four years in secondary schools teaching home-economics and had a further year working in post-primary Aboriginal education. She had worked at her current school for 11 years, and had taught Year 7 for five years. For the past two years, she had been tandem

teaching with another teacher, as she was one of the deputy principals. She had always taught science in her Year 7 class.

At high school Ms Brown had studied physics and chemistry in Year 11 and biology in Year 12. She trained at an institute of technology where she completed a home science diploma and had since attended one science based in-service. The other teacher in the study, Mr Carter, had worked as a science support teacher a few years earlier and Ms Brown felt that this had enhanced her science teaching. Both Year 7 teachers taught the same topics during the year using the same programs and Ms Brown again felt that this collaboration helped her science teaching.

Science knowledge

In unrecorded conversation Ms Brown indicated that she had taught electricity several times before and felt that her knowledge was adequate although she was less confident with this topic than with some others. In post discussions she felt that she had not understood the concept of parallel circuits well enough to be able to explain it clearly to the students, although after a class discussion with students the day after the relevant lesson she felt that the students did understand them. She considered that the activity lesson for parallel circuits had not progressed very well for a variety of reasons:

Ms Brown ... When I was doing these lessons I'd sort of prepare the night before and I think this lesson particular lesson was done early in the day too and I'd had a lot of, multitude of interruptions. I'm not trying to make excuses, I wasn't super confident and I'd had all these other interruptions which sort of completely blew my, this was even before I got into the classroom you know, just in the office when you get to school. I get to school fairly early, about quarter to eight, and different incidents have arisen which had to be dealt with straight away, get to the classroom sort of think, got to get this organised and yeah so. And the kids were high too and I, they were high. It didn't really help unfortunately. It was a lousy lesson and I came out thinking I've really blown this, yeah. (Post interview)

Ms Brown had a collection of curriculum and reference material which she used to extend her understanding of science concepts

Philosophy

Ms Brown felt that science was an important part of the school curriculum because it helped develop students' thinking skills. She also considered that good primary science teaching encouraged students to go into science at high school. She felt that whole-class questioning and class discussions helped students to develop their

understandings but conceded that sometimes time for discussion was limited. Ms Brown considered that students did not often think about what they were doing:

Ms Brown I think um sometimes they come in and think it 's just a bit of a game. Something to fiddle with and play around with and I've found sevens aren't risk takers when it comes to making uh drawing conclusions. They want to know if the answers right before they will have a go.

She was aware of gender equity issues and this was also a consideration within the school. She showed concern for the level of written and graphical work produced by the students ensuring that the work was clear and well labelled.

Science Topics and Lessons

Science topics

Science topics were chosen in collaboration with the other Year 7 teacher. The topics covered were mainly in the physical sciences but they had also completed some Transition Science (Curriculum Branch, Education Department of Western Australia, 1986) activities designed to assist the transition from Year 7 to high school, which included biological topics.

Lesson structure

Ms Brown's lessons were normally one hour long but, because of the time slot, the lessons in the study were about 75 minutes each. She indicated that, when she was teaching full time in the classroom, she had an extra half hour lesson during which the students generally completed their write-ups, but since taking on extra responsibilities she had not had this extra time.

Most of Ms Brown's science teaching involved hands-on activity work, usually in groups but occasionally individually, with the students also doing some partner work in mathematics. The tandem teacher also used group work in social studies.

Ms Brown's science lessons had a similar structure to those in the study although she indicated she normally included less discussion. She generally expected the students to do formal write-ups of their investigations consisting of an aim, the materials used, the method used, the results and a conclusion.

Ms Brown followed the format of the first three lessons, completing them in the lesson time. The last lesson was not finished in the allotted time and Ms Brown said she would complete the work, the Summary sheets, after lunch. Unfortunately, as Deputy Principal, she was called away but completed the lesson the following afternoon in a 30 minute lesson segment.

Ms Brown's Approach to Teaching the Electricity Topic

Prior to the series of lessons Ms Brown taught two of the lessons on light that were supplied.

Use of Class Time During Electricity Lessons

The total amount of teaching time for the topic of electricity was five hours 41 minutes and, as the school did not use a siren at the end of lessons, they sometimes continued into recess resulting in some restlessness from the students. Forty-four percent of class time was used for group work which included hands-on activities and within-group talk about the activities. A further 25% of class time was used for whole-class discussions and 31% was used for class and task management. There were very few interruptions to the lessons. Generally Ms Brown followed the lesson outlines.

Lesson 1: Circuit Construction, Current and Current Flow

Ms Brown followed most of the lesson outline. Students drew possible circuits on paper with selected students invited to draw their ideas on the blackboard. They then tested the suggested circuits. After each activity there was a whole-class discussion although the discussion after construction of circuits using one battery, one globe and one wire contained no conceptual ideas and only identified working and non working circuits. At this stage Ms Brown reminded students that they needed to discuss where the electric current was in the circuit and the direction in which it was flowing and then conducted a brief whole-class discussion on the topic. After the students had constructed circuits using one battery, one globe and two wires, the whole-class discussion developed some understanding of connecting points on a battery and reasons why circuits might not work. Ms Brown did not allow students to discuss the Summary Sheet but, as a long period of time was allowed for each section of the sheet, the students worked together. The ammeter demonstration was completed with limited explanations from Ms Brown. Prior to the role-play, she explained what it would demonstrate but the discussion afterwards was limited. As the lesson was completed early, it was suggested that the teacher allow students to go back to activity one as only two of the possible four circuits had been constructed by the students.

Lesson 2: Conductors and Insulators

Ms Brown followed the lesson format with detailed discussions about which materials were conductors and which were insulators extending the discussion to relate the concepts to real life. The students incorporated switches into their circuits but the

ammeter demonstration was omitted. Some predictions were made and justified prior to the final activity, where the students constructed circuits to examine the difference in globe brightness when different voltage globes were used with a 1.5 volt battery. However, there was no conceptual discussion after the activity, only feedback as to the brightness of the different voltage globes. The groups discussed and completed the Summary Sheets. At the end of the lessons, Ms Brown handed out a related home project constructing either a nerve tester or a quiz board and related this to the identification of conductors and insulators.

Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages

By this lesson Ms Brown considered that students were not co-operating well in their groups and organised the groups to sit boy, girl, boy, girl numbering the group members. After a brief review of the final activity in Lesson 2, the class started the first activity, adding extra batteries to a circuit containing a 4.8 volt globe. Ms Brown talked the students through the first part of the worksheet, asking the students by number to do parts of the activity so all group members participated. When working independently, the students were each instructed to do a part of the activity and pass it on to the next person. After each activity, selected students were asked to draw the circuits they had made on the blackboard and Ms Brown asked the students to mark the positive and negative on their circuit diagrams with the relevance of this being covered during the discussion. She generated an understanding that the addition of batteries increased the voltage that was available. An incorrect circuit produced by one group generated a useful discussion of where circuits needed to be connected to allow the 4.8 volt globe to light brightly.

Prior to the second activity, connecting globes in series, the students were asked to predict what might happen with some students asked to justify their predictions. After the activity there was some conceptual discussion indicating that the addition of extra globes where one 1.5 volt battery was the source of energy resulted in dimmer globes because of the amount of energy available. Ms Brown did not include the ammeter demonstration or demonstrate globes blowing from the application of too much energy.

There was a whole-class discussion based on the Summary Sheet prior to their completion but students were not given group discussion time. However, students were talking in their groups as they completed the Summary Sheet.

Lesson 4: Parallel Circuits

Lesson 4a was at an earlier time than usual and Ms Brown had a difficult start to the day with interruptions relating to her role as deputy principal. She had found less time to prepare for the lesson and felt less confident. Dancing lessons were starting that morning and this prospect was a major distraction. In this lesson there was initially a very brief discussion related to the home project. Ms Brown then drew the classes attention to the class investigation, comparing the length of time similar simple, series and parallel circuits would continue working. The first group activity was constructing circuits with globes in parallel and the students were again numbered in their groups and expected to take turns. The construction of a series circuit instead of a parallel circuit by the Focus Group allowed Ms Brown to review series circuits and explain the difference between globes in series and parallel. However, the discussion relating to the results of removing a globe from a parallel circuit was inconclusive. The second activity was connecting batteries in parallel. The whole-class discussion relating to any change in the brightness of the globe when extra batteries were added in parallel was ambiguous, but during individual teacher contact with groups it appeared most groups did not consider the brightness changed. The lesson plan was followed up to the Summary Sheets stage when Ms Brown imposed restrictions on the changes that could be made to the drawn circuit. The students were having difficulty and the teacher, on demonstrating the flow of current through the ammeters, recognised that the imposed restrictions did not allow students to solve the problem. As it was the end of the lesson time, and the class investigation had only shown limited changes, it was decided to carry this investigation, and the Summary Sheets over to a follow-up lesson. The circuits were disconnected and restarted before Lesson 4b, the following day. During this lesson the class investigation was discussed together with the response that was needed on the Summary Sheet and then the Summary Sheets were completed.

Mr Carter and his Class

The Class

This class consisted of 30 students with 17 girls and 13 boys. There were no students that did not have a home language of English or who were born overseas.

Student characteristics

Mr Carter considered that most of the class were excellent workers but that eight of the boys could not be allowed to work together because their behaviour deteriorated

and they did not follow instructions. He commented that most students worked well in groups although observation indicated that in some groups the boys were dominant and tended to be the equipment users. Mr Carter felt that in this class it was essential that the students work in mixed gender groups because of the boys behaviour in all boy groups.

Interviewer You had the groups so they were mixed girls and boys. Do you feel it would have made a lot of difference if you had had all girls in one group, all boys in the other?

Mr Carter Um. Probably would have got a bit better cooperation at times. Uh, though the boys would not have cooperated well. They would have just gone ahead and done you know. The boys have very little self discipline and they needed the girls there to keep them on track. (Post interview)

Mr Carter did not consider they were good at following either verbal or written instructions. He stated that they did not listen to all instructions given and, where written instructions were used, the students tended to read the first instruction and then do what they considered was the activity. Mr Carter allowed the students freedom to continue activities and allowed the students some independence.

Composition of groups

All the groups were mixed gender groups and stayed the same throughout the lessons. Most groups seemed to work well together although one group in particular was less cohesive and needed Mr Carter's attention more frequently. The Focus Group, at a superficial level, appeared to work together effectively but the recordings revealed very low levels of cooperation and a high proportion of off-task behaviour.

Students' academic ability

When asked to rate his students on a scale of one to five shortly after the study, where one was very high and five very low, no students were level five, with nine at level four. Ten students were at level three, six students at two and five at one.

The Classroom Environment

Mr Carter's class worked in the same room as Ms Brown's class. The electricity posters were displayed although Mr Carter did not think the students had looked at them. He considered that students rarely looked at the materials on classroom walls unless they were specifically directed to them.

Mr Carter

Academic background and teaching experience

Mr Carter had been teaching in primary schools for 13 years with experience in three schools. He had been teaching a Year 7 class at his current school for three years

but had two years of Year 7 teaching at a previous school and had also taught Year 7 science as a support teacher for two years. At high school he studied general science, chemistry and physics in Years 9 and 10 and biology in Years 11 and 12. During his teacher training he did two extra science units, one of which was an environmental science course and he had also attended a variety of science seminars.

Science knowledge

Mr Carter was aware that his knowledge in some science areas was limited, and commented that there were students in the class who would know more about electricity than he did. On the one occasion when he was unsure he asked a more knowledgeable teacher in the school. Mr Carter appeared unaware of the understandings that students might hold regarding electric current and flow:

Mr Carter It actually showed up in their diagrams of circuits they thought would work. I was amazed when some of the kids thought you just got a battery from, a wire from one end of the battery.

Philosophy

Mr Carter felt that science was an important part of the curriculum as it was practical and “gets the students thinking”. He also felt that it should be fun and, if so, students would be encouraged to do more. He felt that students developed their conceptual understandings of science very slowly but considered that most students had some knowledge and his task was to get them to recognise that knowledge. He had attended courses on facilitation and said he tried to use these skills in the classroom. He also felt that students would go to a more knowledgeable student for information. This was particularly relevant in the electricity topic as two students considered themselves very knowledgeable about the topic.

He considered that students enjoyed science and learnt a lot from hands-on activities but that they did need to learn to talk about the investigations as they tended to talk about what was happening not why it was happening, and that conclusions were not often reached. He suggested that students have to be led to the understandings.

Mr Carter Yes. They definitely talk about it, but they can do all the talking they like until they actually get their hands on and do something and prove that they've got a hypothesis that actually is correct. (Early in first interview)

later

Interviewer Do you think when they are talking in their groups and they are on task that they are actually talking about what's happening or what they're doing?

Mr Carter *Yeah. They, no they don't talk enough about the whys. They talk about the what is happening. There's very little conclusion. Um, they have got better but, um, as I said, this class isn't a super academic class. Yeah, sure I've got my individuals that are lmt because they are a much more practical sort of bunch of kids they do um they do need leading.*

Science Topics and Lessons

Science topics

Mr Carter taught the same topics as Ms Brown in his Year 7 program. He showed enthusiasm for the topics when discussing them and seemed to generate this enthusiasm during the lessons. He also sometimes arranged for a teacher from the local high school to come and do occasional 30 minute science lessons and felt this was useful because the high school teacher had a deeper understanding of the topics.

Mr Carter tended to avoid the biological sciences because he felt more confident in the physical sciences and also considered students enjoy hands-on physical science activities more:

Mr Carter *No. Um mainly I want the kids to get their hands on to stuff and to get involved in it and plus I'm more competent doing you know physical sorts of science. Um, yeah. So that's why I tend to steer that way, and I just think the kids react better to it if there's a lot you know they can get their hands on.*

Lesson structure

Mr Carter's lessons were normally an hour long and a similar length of time was allowed for the lessons in the study, although he admitted that if any lesson was going particularly well he would extend the time. This was demonstrated in the first of the electricity lessons when the lesson ran for nearly two hours. His normal science lessons were similarly structured to those taught in the research, although he included fewer questions and less writing. However, the writing he required from students was generally a formal science write-up including aim, materials, method, results and conclusions.

Mr Carter had been doing a considerable amount of group work in areas other than science encouraging the students to discuss, co-operate and reach consensus and considered the students were good at working in groups:

Mr Carter *Particularly to try to get them into cooperation and consensus rather than arguing and just you know one bloke decides what we're going to do sort of thing.*

Researcher *Yes.*

Mr Carter *We do. And they are very good at group work this mob.*

Examples given by Mr Carter indicated that science tended to creep in to other curriculum areas in ways that would extend the students' understanding. He conceded that integration did not happen on a regular basis and that the amount was not large.

Mr Carter's Approach to Teaching the Electricity Topic

Prior to the series of electricity lessons Mr Carter taught two of the lessons on light that were supplied. Generally, when the children came into the classroom, they organised their seating quickly but tended to be off-task at the beginning of the lessons. Apart from the first lesson, Mr Carter's lessons generally ran for about an hour, although the students did not complete the Summary Sheets during this time but either had class time after recess to complete them or they completed them for homework.

Use of Class Time During Electricity Lessons

The total time for the electricity lessons was five hours 34 minutes with a further unknown amount of time used to complete the Summary Sheets for homework. When the sheets were completed for homework, the varying quality and quantity of work that was handed in suggests that the time varied from student to student. Forty-five percent of lesson time was used for group work which included hands-on activities and group discussions. A further 30% of lesson time was used for whole-class discussions and 25% was used for class and task management, with a very small amount of time taken up with interruptions.

Lesson 1: Circuit Construction, Current and Current Flow

Before starting the activities, Mr Carter discussed safety explaining that the students should not consider using the electric current in their houses. He followed most of the lesson outline with students initially drawing circuits that might be constructed using one wire, a battery and a globe on paper and selected students drawing circuits on the blackboard. After the circuits had been constructed and tested, Mr Carter used the blackboard drawings to identify working and non-working circuits with the students very involved in the discussion. During this time two Focus Group students had been blowing globes and Mr Carter used this as a teaching point for the whole class. The students then drew diagrams of possible circuits using two wires, a battery and a globe and, again, selected students drew them on the board. The groups constructed their circuits and Mr Carter then asked which of the circuits drawn on the blackboard worked. There was little conceptual discussion although some understandings might have been developed by some of the descriptions used. Mr Carter copied the focus questions onto

the blackboard and asked the groups to discuss them. As the group discussions appeared to be going well, Mr Carter extended this lesson to one hour and 48 minutes, and did the ammeter demonstration and role-play activity in this time. He also visited some of the groups and facilitated their discussion on direction of current flow and conducted a whole-class discussion about what was needed to make a working circuit. During the ammeter demonstration Mr Carter explained how a globe holder worked, after encouraging the students to brain-storm why the circuit was not working. The groups worked on the Summary Sheets and, if unfinished, the students were asked to complete them for homework

Lesson 2: Conductors and Insulators

Mr Carter started the lesson by reviewing some of the previous week's work. The students then constructed a circuit to test materials for conductivity with Mr Carter asking them to break the circuit by disconnecting two alligator clips and then find some way of getting the circuit to work again without directly re-connecting the alligator clips. The students found a variety of ways to re-connect the circuit using conductors or re-connecting the circuit in a different way. When the polystyrene foam and the drawing pins were connected into the circuit with the drawing pins apart, Mr Carter questioned the students to generate the words 'conductor' and 'insulator'. The students then tested the supplied materials. Mr Carter blackboarded a list of conductors and insulators and asked the students, in their groups, to work out a common property of conductors and a common property of insulators. Having obtained a common property from one group he then asked the students to produce some 'therefore' statements suggesting the results of putting these items in a circuit. Mr Carter used the ammeters to demonstrate that when the circuit is disconnected there is no flow of current, generating this idea by discussion with the students. Before testing the 1.3, 2.6 and 4.8 volt globes with a 1.5 volt battery the students, in their groups, were asked to predict what might happen. They then tested the globes and recorded their answers. Rather than ask the students to discuss the Summary Sheets, Mr Carter asked the students to talk about what they had done in the lesson with the students completing the Summary Sheet for homework. The discussion appeared very limited with several groups socialising.

Lesson 3: Series Circuits and the Relationship between Battery and Globe Voltages

Mr Carter started the lesson by reviewing some of the things that had already been covered, and also discussed what happened when a globe was blown. He then reviewed the final activity of the previous week and asked students to discuss in their

groups how a 4.8 volt globe could be made to shine brightly. After bringing the class ideas together, Mr Carter told the students to make the globe brighter. When the groups had completed their new circuits, selected groups demonstrated them and Mr Carter drew diagrams of them on the blackboard. The connections were strongly emphasised. The students added the third battery and again, selected groups showed and talked about their circuits. Mr Carter drew the class's attention to one circuit where the students had incorporated conductors as well as extra wires, and used it to demonstrate what happened when one battery was reversed in a series circuit, using an analogy to help the explanation. In the second activity the students were intended to initially make a circuit with one 1.5 volt battery and a 1.3 volt globe and then add, one at a time, a further two globes in series, so that they could see the brightness of the globes diminishing. Mr Carter asked the students to immediately join the three 1.3 volt globes in series with the result that some groups were unable to get three globes to light and they had not tested fewer globes. The students were asked to discuss why this was happening but there was no further whole-class discussion on the topic. Mr Carter had photocopied the focus question sheets and asked students to discuss the questions. The Summary Sheets were not discussed but the students were allowed class time after recess to complete them. The ammeter demonstration was not used.

Lesson 4: Parallel Circuits

The lesson started with a review of some of the things that had been covered in the previous three lessons. Mr Carter then drew the students' attention to the whole-class investigation, comparing the length of time similar simple, series and parallel circuits would continue working. He then asked the students to discuss how they would add an extra globe to a simple circuit without disconnecting the circuit, with the students then constructing the circuit. After the parallel circuits with two globes had been constructed, selected students drew diagrams on the blackboard with Mr Carter describing the circuits that they had made. The students were then asked to add a third globe to the circuit and test to see what happened when a globe was unscrewed from a globe holder. The discussion about the effects of removing one globe was misleading as the students considered that, when a globe was removed, the remaining globes were brighter and Mr Carter accepted a student response indicating that there was now more energy available for the remaining two globes. The second activity, connecting two batteries in parallel, was completed with the class discussion indicating that the globes had gone brighter. Once again a student drew his circuit on the blackboard with Mr

Carter describing it. Mr Carter asked the class what would happen if one battery was reversed in a parallel circuit and asked them to try it. He gained an explanation from a class member and used an analogy and role-play to reinforce the explanation. Mr Carter then drew the students' attention to the class investigation and asked them to offer statements about what had happened. The students were given copies of the focus questions from the lesson outlines and asked to discuss these. The Summary Sheets were completed without further discussion in class time after afternoon recess.

Summary

The three classes were in similar situations and, architecturally, were similarly styled schools. The student and staff population varied in size and, at both schools, there was a perception that science was not well taught. All three teachers were experienced teachers who had taught Year 7 students for some time, and they were all confident science teachers, with past study experience in the physical sciences, although Mr Avery had the most experience. All the teachers felt that science was an important part of the curriculum. The classes varied in size but the students within the classes had a similar range of abilities. All the teachers followed the lesson outlines to some degree with some differences in content.

The time allowed for the lessons in Ms Brown and Mr Carter's classes was similar, although Mr Carter's students did not complete the Summary Sheets in this time, with Mr Avery spending about a half-hour extra on his lessons. This is accounted for by the extra lesson conducted by Mr Avery which would have given the students more practise in building the circuits but in which there was little conceptual discussion.

The lesson area that showed the most difference was the amount of time allowed for and the nature of the Summary Sheet discussions and completion. The students in Mr Avery's class only completed two Summary Sheets, one of which was completed without discussion. Ms Brown's class completed all the Summary Sheets within the lessons, with one sheet completed with no official group discussion; one with a whole-class discussion and no official group discussion; one with group discussion only and one with both whole-class and group discussion. Mr Carter allowed group discussion in the first lesson, and had the sheets completed during the lesson and finished for homework. In the remaining lessons there was no group discussion specifically on the sheets, although the students usually had the focus questions to discuss, with the

students completing the sheets either in class after recess with no further discussion, or for homework.

Another area of difference was the use of the focus questions. Mr Avery used them as questions for the group discussion in Lesson 1 and discussed some of them with the whole class afterwards. He also used them in most of the end of the lesson review sessions. Ms Brown did not refer to them during the lessons with her lessons sometimes not covering specific points because of this. Mr Carter used the focus questions to promote discussion in the groups in three lessons, but did not include any whole-class discussion on them.

This Chapter has provided a general overview of the three classes in the study. The following three chapters look at each class in greater detail. Chapter 5 examines the whole-class interactions and the ways that the teachers managed and conducted the discussions and demonstrations; Chapter 6 outlines the teachers' interactions with the groups and the children's level of participation; and Chapter 7 examines the Focus Groups and the way the group members managed the activities and interacted with each other.

CHAPTER 5

Whole-class Teaching in the Three Classrooms

Overview

This Chapter is an overview of the teaching and interactions that the three teachers engaged in when conducting whole-class discussions. Following the overview of the three teachers' teaching, the discussion leads to the development of assertions. These are numbered in order of presentation throughout this thesis and have a prefix which indicates the chapter number in which they originate.

Mr Avery

Classroom Management

Mr Avery was a quiet teacher who maintained a friendly attitude towards the students and he allowed them to call him by a shortened version of his name. He solved most potential control problems during whole-class discussions by mentioning the relevant student's name in the course of his talk, or by asking an off-task student to respond, although on occasion stronger measures were taken:

Mr Avery: Bob, can you disconnect that and you go and sit right in the back corner as well. And I'll have some more to say to you tomorrow. (Lesson 3 4a)

Off-task behaviours occurred more often in discussions during the lesson when students had equipment on their desks, rather than at the beginning or end of the lessons when the equipment was not available. To reduce off-task behaviours during discussions that involved demonstrations, the students were often asked to come to the front of the class. For the discussions at the end of the lessons students were asked to turn their chairs around to face the teacher and appeared generally attentive.

Whole-class Discussions

Mr Avery's discussions were quiet but animated, involving many of the students in the class. Students offered suggestions and ideas and were willing to argue points with which they disagreed, with Mr Avery accepting and using their ideas. In one lesson, after Mr Avery had used an analogy to explain how the parallel circuits worked, a student suggested another way of connecting the globes in parallel. This was drawn on the blackboard and discussed. The students also asked questions about the topic under

consideration and questions which were not necessarily directly related to the current activity but demonstrated their interest in the topic:

Student But how does the battery run out? (Lesson 1b)

Mr Avery used circuits constructed by the students and student blackboard drawings to illustrate explanations. He generally asked students to do any blackboard drawing whilst the class were still working on activities. This resulted in the class paying attention when the diagrams were used in the discussion as they did not have to watch the diagrams being drawn. If students were drawing on the blackboard whilst the other students watched, Mr Avery explained the diagrams as they were drawn, maintaining the students' attention. He frequently used practical demonstrations, blackboard drawings, posters and analogies to explain concepts, with practical demonstrations close to the students so they could see clearly. He also asked students to assist in the demonstrations. As he used the teaching aids, he constructed explanations that were able to be understood by the students and related the activity to the concept being taught.

The students were involved in evaluating the blackboard drawings not only through discussion, but also making the necessary changes to correct the diagrams. On one occasion, when the students were watching, a student drew a diagram on the blackboard with Mr Avery explaining her circuit as she drew. However, the globe did not appear to be attached to the battery. The attention the class paid to the work was emphasised when this was queried by another student:

Student But how would it stick to the battery? (Lesson 1b)

Interactions and Use of Time in Lessons

This section examines the types of interactions that occurred in whole-class discussions; the way the time was used; and the use and explanation of scientific and non-scientific vocabulary.

Types of interactions during whole-class discussion

Fifty-seven percent of the total lesson time was used for whole-class discussions including task and class management. This time was used for two broad purposes: reviewing previous work and treating current activities. Mr Avery used different types of interactions including open questioning where students, rather than presenting

specific, factual, correct answers, were expected to think and produce a variety of explanations; closed questioning, where a factual correct answer was anticipated and once found the teacher moved to a new question although he sometimes expanded the student’s answer; and teacher exposition where the teacher dominated the interactions, usually describing and explaining, sometimes using analogies. .

An analysis of the interactions shows that 64% were made by Mr Avery and 36% by the students. Generally, Mr Avery’s utterances were longer than those of the students.

Reviews

Mr Avery spent over 30% of the discussion time reviewing work completed during that or previous lessons (Figure 5.1) with 28% of Mr Avery’s utterances and 26% of student utterances related to this (Figures 5.1, 5.2).

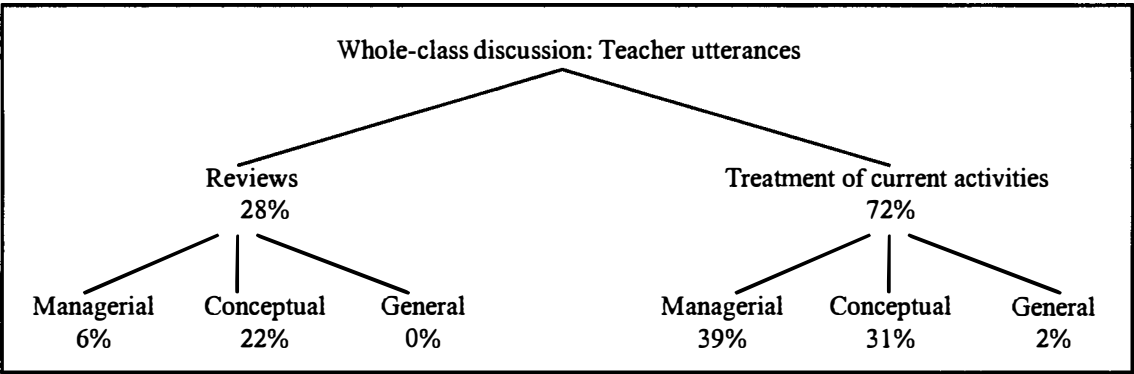


Figure 5.1. Use of whole-class discussion time: Teacher utterances

Mr Avery controlled the direction of the reviews although he was willing to be diverted. He reviewed at the beginning of most lessons and the end of all lessons and also during two half-hour lessons when the investigations were discussed and written-up. He also reviewed ideas that students needed to understand within the lessons, addressing most of the concepts being covered during his review sessions, with some being visited more than others. The frequency of the reviews allowed opportunities for the students to make links between lessons and between parts of the lessons and allowed students who had been absent to find out about previous activities. There was no science equipment on the desks during the final review sessions, resulting in a class that was generally attentive and involved. When reviews were held during lessons, Mr Avery often asked the students to come to the front of the class although some were held with students at their desks. The students were generally attentive, but some were distracted

by the availability of the materials. Only 6% of the utterances were related to management with the remaining being conceptual but, because he tended to use circuits in his discussions, there was a proportionately high level of task related comments. Mr Avery used a variety of aids during the review sessions, including models, posters and blackboard work. The class management comments occurred mainly when the students were getting organised for the discussion.

Most of the conceptual discussion involved teacher exposition and closed questions but 3% of the questions were open (Table 5.1). These usually occurred at the beginning of discussion on a topic to see what the students could recall.

<i>Mr Avery</i>	<i>We changed the the globe. What happened to the brightness?</i>
<i>Student</i>	<i>Oh, it got duller.</i>
<i>Mr Avery</i>	<i>Yeah. It didn't seem to have the same energy. And when we used the 4.5 one and we still used the same 1.5 volt battery it didn't produce much of a glow at all. So what's that tell us about the globe itself and the filament that's inside it, Zoe?</i>
<i>Student</i>	<i>Um that it needs the volts on the casing of the globe to make it light up to its best. (Lesson 3)</i>

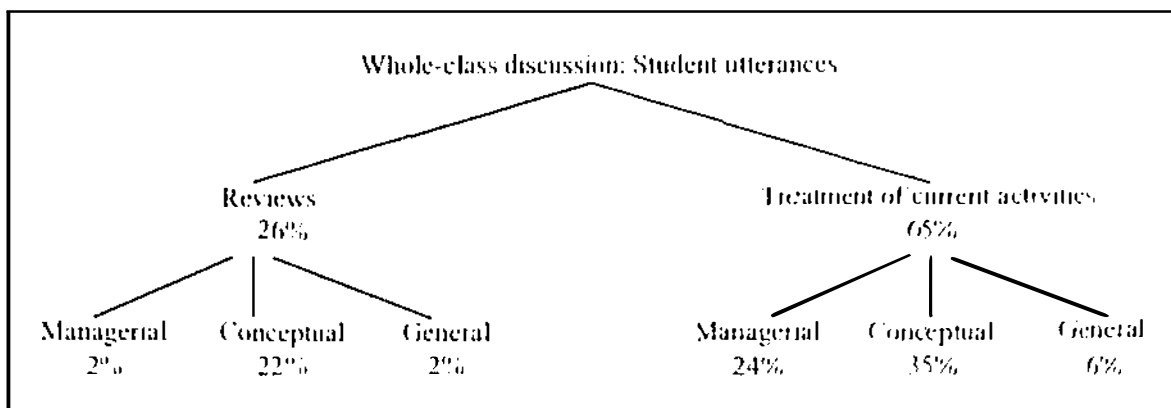
The range of question types used by Mr Avery allowed more students to respond and a wider variety of responses to be offered.

The lesson outlines suggested focus questions that could be used to help manage the reviews. Mr Avery used these on two occasions but did not complete the discussions based on them. However, most of the concepts addressed by the focus questions were covered by Mr Avery in his comprehensive discussions.

Student participation in reviews

Mr Avery ensured that a variety of students were asked to respond to questions and the students were usually attentive and interested in the discussions. Many of them offered suggestions and ideas, and answers which included extra information. They also asked questions which did not directly relate to the discussion but which showed evidence of thinking.

A small percentage (2%) of student utterances was related to task management where students were involved in demonstrations and were suggesting changes to the circuits. Most of the student utterances were conceptual with most being responses to closed questions (10%) although 4% of utterances were responses to open questions (Figure 5.2). A few closed questions (1%) were also asked by students (Table 5.1).



N.B. A further 9% of student comments were unintelligible

Figure 5.2. Use of whole-class discussion time: Student utterances

Treatment of current activities

The remaining 70% of whole-class discussion time was used to discuss the work in which the students were currently engaged with the remaining 72% of utterances by Mr Avery and 65% by the students related to this (Figures 5.1, 5.2). Thirty-nine percent of Mr Avery's utterances related to management, most of which referred to task management, with 11% related to managing student behaviour. The percentage of teacher utterances where understandings might be developed (31%) was lower than those related to management (39%).

Teacher and class interactions

Part of the whole-class discussion time was used to give instructions for the activities and Mr Avery usually asked a student to read these, sometimes repeating the important points. The groups then progressed through the activities, usually at their own speed, but occasionally being directed by Mr Avery. During the time when discussion was intended to develop understandings, two-thirds (19%) of the utterances were explanatory and one-third (11%) questions, with nearly half of these (5%) being open (Table 5.1). Mr Avery's explanations were always clear and understandable and he often involved the class in generating ideas before giving the correct explanation. The actual time spent on open questions was longer than that spent on closed questions because of the length and variety of the responses that were accepted and elaborated upon. Open questions occurred at any stage of the lesson. Sometimes they were used to generate predictions, and sometimes to ascertain the understandings that students had developed:

Mr Avery Paul just join that one on to that end there. No, uh you can leave that on. Now prediction. Are they going to be any brighter? (Lesson 3/4a)

After accepting a variety of answers in a neutral manner, Mr Avery asked a student to connect in the extra globes with the ensuing discussion explaining what had happened.

After the activity testing for conductors and insulators in Lesson 2, Mr Avery drew the students' attention to a piece of galvanised wire which had not conducted the electric current:

Mr Avery Okay, it it's a metal. Maybe it didn't work. What is one of the reasons why it may not work? (Lesson 2)

The students suggested a variety of reasons but did not arrive at the correct answer and Mr Avery pointed out the different colour of the surface of the wire and the inside and related this to the idea of an insulating coating.

Mr Avery showed an awareness of the types of understandings students may have and used this to obtain a range of responses. A common misunderstanding that students might have relates to the direction of current flow in a circuit. In Lesson 1a, Mr Avery questioned the students to ascertain their beliefs and, in the same lesson segment, demonstrated some other aspects of current flow. There were diagrams of working and non-working circuits on the blackboard and Mr Avery used the working circuit diagrams and a cardboard template of a battery to help demonstrate the ideas that were discussed:

Mr Avery Okay. So the electric current we said is the flow of electricity. Where's it flowing from? That's the big question.

Student From the battery going into the globe.

Mr Avery Okay, it's coming from the battery and it's going to the globe. Okay, that's the flow. Now in order to happen, what would happen if I did that. (He erased part of a wire in a working circuit) There's my wire, I've cut it.

Student It wouldn't work.

Mr Avery It wouldn't work. So have we got a flow now?

Students No.

Mr Avery Okay. I've got my battery. Here's my battery everyone. (He held up the template of a battery) Have I got a flow of current? It's stored with lots of energy in there. Have I got a flow of? Who thinks it has? Hands up. (A few students, rather tentatively, put their hands up) Who thinks it hasn't? (Some students, again tentatively, put their hands up) Okay, we haven't got a flow. We haven't got a circuit. We haven't got a continuous path. If I put that in there (He placed the template on a diagram of a working circuit) There it is. it's flowing. This one (He moved the template to

another working circuit) *Around it's flowing. Does anyone know where it starts and where it ends? Who'd like to have a guess at it? Bob.*

Bob *It ends at the plus.*

Mr Avery *The positive. There's our positive, there is, you have a look at your batteries. You've got a sign on there, a positive. See if you can locate it. There it is positive, up there (Showed on a battery) Therefore the bottom part would be negative. So Bob says that it would start it would end up here back to the positive. Good work. So he's suggesting that. Who agrees with Bob? It comes from here this is the negative part and it goes right around to there in through the filament and back through there. Who agrees with that? (Several students raised their hands) Okay. Who's got another opinion? Ian.*

Ian *Um the um the flow comes from both ends and finishes in the globe.*

Mr Avery *Okay. So the other theory now is that it starts here and it also starts there and then it goes from in there, in up there, it works in there and it also at the same time, it's got to come through that way. (Used a circuit diagram to demonstrate current flow) So we've got energy coming from both sections. Okay, that's another theory. Who else has got a theory? Eva.*

Eva *Um that it comes from the positive end.*

Mr Avery *Okay, you're saying it goes the other way.*

Eva *And it doesn't stop.*

Mr Avery *So it comes from the positive there and goes around that way, comes through here in there and back to the negative. Okay, who agrees with that theory? (Several hands up) All right, okay. (Lesson 1)*

Mr Avery reinforced ideas in a variety of ways with the students' understanding being developed by the use of diagrams, analogies, discussion, demonstrations and group work. The demonstrations, in which the students often participated, were linked closely with the activities in which the students were engaged. Student blackboard diagrams were used to demonstrate ideas, but usually these were drawn whilst the other students were working. However, if the students were drawing and the class watching, he offered explanations and ideas as the diagrams were drawn, helping to maintain the students' interest. He often used models made by the students to reinforce or demonstrate ideas. His wide range of knowledge of this topic allowed him to present information that was outside the concepts being discussed, such as static electricity and an explanation as to why some globes started flashing. However, he was also able to use ideas that the students came up that were not included in the lesson outlines. Mr Avery generally covered all the materials in the outlines, but adapted them to fit his style of teaching.

Student participation

As with all Mr Avery's discussions the students were either turned around in their chairs or moved to the front of the class if a demonstration was involved. The students were usually attentive and showed interest and were keen to participate

Student utterances during this type of discussion again were similar in number to Mr Avery's. There was a high proportion of unintelligible utterances due to recording difficulties, and some that were unrelated to the topic. Students made fewer utterances related to management. During the conceptual discussion the students were involved in constructing explanations by Mr Avery's methods of questioning. Most of their utterances were responses to questions, with 9% being responses to closed questions and 13% were responses to open questions (Table 5.1). The responses from the students were often extended giving extra information:

Mr Avery *What normally happens to produce the light?*
Student *The energy from the battery comes through and gives the globe power to shine but because in the series one, with the series one, it has to go around and there's not enough to power them all. (Lesson 3/4)*

This gave Mr Avery an opportunity to recognise students' understandings, and he was often able to develop better understandings using this knowledge. Students did ask a small number of closed questions (3%) which often demonstrated the students' attention and were requests for clarification:

Student *Mr Avery, wouldn't the current run through that part as well? The metal part? (Lesson 3/4)*
Student *What do you mean by swapping it over? (Lesson 1)*

A further 7% of the utterances involved the students either telling Mr Avery what had happened in their investigations or, more frequently, offering suggestions or reasons why something had happened in demonstrations:

Student *Maybe it's not connected properly or something. (Lesson 4)*
Student *Oh, that's because you've changed the battery around. (Lesson 1)*

Most of Mr Avery's utterances were related to management, some of which included conceptual information, with explanations the next highest, and questions, both open and closed, also quite high. The students comments were also often related to management, but slightly more were responses to questions, mostly to closed questions (Table 5.1).

Table 5.1
Interactions Between Mr Avery and Students in Whole-class Discussions

Type of utterance	Percentage of utterances from:			
	Review		Treating current activities	
	Mr Avery	Students	Mr Avery	Students
Managing class or group	2		11	2
Managing equipment			2	2
Managing task	4	2	26	20
Explanations	8		11	1
Open questions	3		5	
Responses to open questions		4		13
Closed questions	6	1	6	3
Responses to closed questions		10	1	9
Information from students (conceptual)		4		7
Task management (conceptual)	5	3	8	2
Unintelligible		2		9
Other			2	6

Use and Understanding of Scientific Vocabulary

Introduction

Although Mr Avery used a variety of scientific terms in discussions the students used few of the new scientific terms. The everyday words, such as battery, globe and wires were used frequently.

Mr Avery’s use and explanation of scientific vocabulary

Mr Avery used a mixture of scientific and non-scientific vocabulary offering explanations for some words and not for others. Words that were used frequently and during most of the lessons were the common ones such as battery, globe, circuit, and electricity, with both energy and electrons used fairly often. He also, once they had been introduced, used the circuit names, series and parallel frequently. However, other words, such as conductor and insulator were used infrequently. There were some words that were not explained. These included everyday words such as globe and battery, where explanations may have improved the students’ understanding of circuits and current flow; and also words such as terminal and resistance for which the students may have had everyday meanings which were not easily connected with electric circuits.

The explanations that were offered varied in quality, with some occurring incidentally in the discussion such as circuit and filament:

Mr Avery Okay we haven't got a flow. We haven't got a circuit. We haven't got a a continuous path. (Lesson 1)

Mr Avery The spring inside. That little filament. Okay yes. (Lesson 1)

Circuit, however, was used frequently in situations where the meaning was clearly demonstrated, and other incidental explanations also occurred.

Most explanations were reasonably clear although some were limited as was the description of conductors and insulators:

Mr Avery What are they? A good question. Conductors something that conducts electricity and something that does not conduct electricity. (Lesson 4)

Other explanations were built up from student responses with the explanation then extended. In Lesson 1, Mr Avery asked the students what an electric current was and accepted a flow of electricity, electricity flowing and moving electricity, writing all the explanations on the blackboard. He extended the explanation later in the lesson:

Mr Avery So the flow of the current, the flow of the electricity is actually the flow of the, a new word that I'll introduce, the flow of electrons and electrons go from the negative, the negative, they go to the positive (Lesson 1)

Student use of scientific vocabulary

The students, in the whole-class discussions, used the common words such as battery, globe and electricity frequently and usually as names, although not as often as Mr Avery. Electric current and volts were also used often but the other scientific terms introduced by Mr Avery were only used infrequently. The names of the circuits, parallel and series were only used three times each by students during the whole-class discussions and electrons was only used once. Some words used by Mr Avery such as resistance and terminals were not used at all by the students.

Ms Brown

Classroom Management

Ms Brown appeared distanced from the class with no friendly interactions and she also had some control problems. Much of the off-task behaviour occurred when the class was waiting for selected students to complete blackboard drawings as there was little to hold the attention of the remaining class members during this time. Ms Brown

tended to stop and often strongly reprimand students who were not paying attention, interrupting any discussion.

Students remained at their desks for all discussions and demonstrations although they were asked to turn and face the teacher. However, most students just turned their heads and turned back to their desks as the discussion progressed, and the science materials provided a distraction.

Whole-class Discussions

The discussions in Ms Brown's class tended not to be animated or interesting and were rather slow moving. Although the students were often restless during this time, the actual discussions were very teacher controlled with no students arguing points or suggesting alternative answers. They usually responded with single words or short phrases, with most only responding to the immediate question and offering no extra information and showing little evidence of extended thinking. This not only made the answers less easy to understand, it also limited any opportunities to recognise students' understandings. When the correct answer was obtained Ms Brown moved on to the next question. She often called on knowledgeable students to answer questions.

Ms Brown constantly used blackboard diagrams drawn by students whilst the rest of the class sat and watched although they rarely stayed watching for long and would turn back to their group. Any explanations by Ms Brown occurred at the end of the drawing and were limited. Student participation in these sessions was also limited with few opportunities to evaluate or discuss the drawings and students were often using equipment or talking quietly among themselves. Ms Brown used no analogies or practical demonstrations apart from two of the suggested ammeter demonstrations. These were held at the front of the class with students still at their desks from where they would not have been able to see clearly as the ammeters were small. The discussion in these situations was limited with little opportunity for the students to participate beyond single word responses.

No discussions went beyond those suggested in the lesson outlines and they often did not cover the focus questions.

Interactions and Use of Time in Lessons

This section examines the types of interactions that occurred in whole-class discussions; the way the time was used; and the use and explanation of scientific and non-scientific vocabulary.

Types of interactions during whole-class discussion

Fifty-six percent of the total lesson time was used for whole-class discussions including task and class management. As in all classes, whole-class discussion time was used for two broad purposes; reviewing previous work, and treating current activities. Ms Brown used different types of interactions during whole-class discussion time. These included open questioning where students, rather than presenting specific, factual, correct answers, were expected to think and generate explanations; closed questioning, where a factual correct answer was anticipated and once found the teacher moved to a new question; and teacher exposition where the teacher dominated the interactions, usually presenting information.

An analysis of the interactions indicates that Ms Brown dominated the discussion making 72% of the utterances with the students contributing 28%.

Reviews

Ms Brown spent eight percent of the discussion time reviewing work completed during that or previous lessons (Figure 5.3). Only a small proportion the total utterances occurred during the review time, Ms Brown’s amounting to four percent and the students to 7% (Fig. 5.3, 5.4).

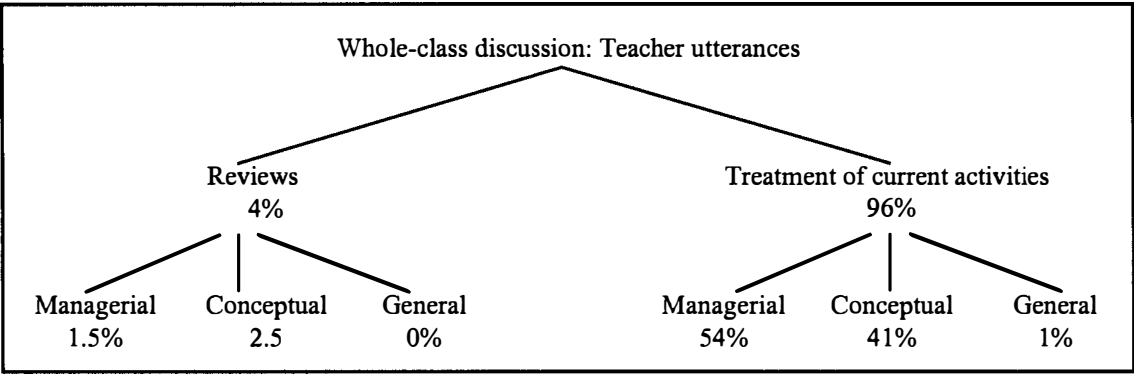


Figure 5.3. Use of whole-class discussion time: Teacher utterances

Only a few short reviews occurred from week to week, with limited reviews during the lessons. Ms Brown held brief reviews at the beginning of Lesson 2 and Lesson 3. The limited number of review sessions meant that few of the concepts were covered in any

detail and the students had less opportunity to make links between lessons and parts of lessons. Students who had been absent had little opportunity to find out what work had previously been completed. Although the science equipment was on the desks during the review sessions at the start of the lessons, it was in a box and not easily accessible.

Ms Brown used no teaching aids during the review times. A small proportion of the time was used for explanations and nearly half the time was used for management. The remainder was taken up with closed questions which usually elicited short answers from the students:

Ms Brown *What did you require in your circuit please, Tina?*
Tina *A battery, a globe and some wires?*
Ms Brown *All right. (writes battery on board) What else did you need?*
Tina *A globe.*
Ms Brown *A globe. (writes globe on board) What else did you require?*
Tina *Wire.*
Ms Brown *Wire. (writes wire on board) Okay, you required those components.*

(Lesson 2)

Ms Brown did not use the suggested focus questions in the reviews and many of the concepts were not covered.

Student participation in reviews

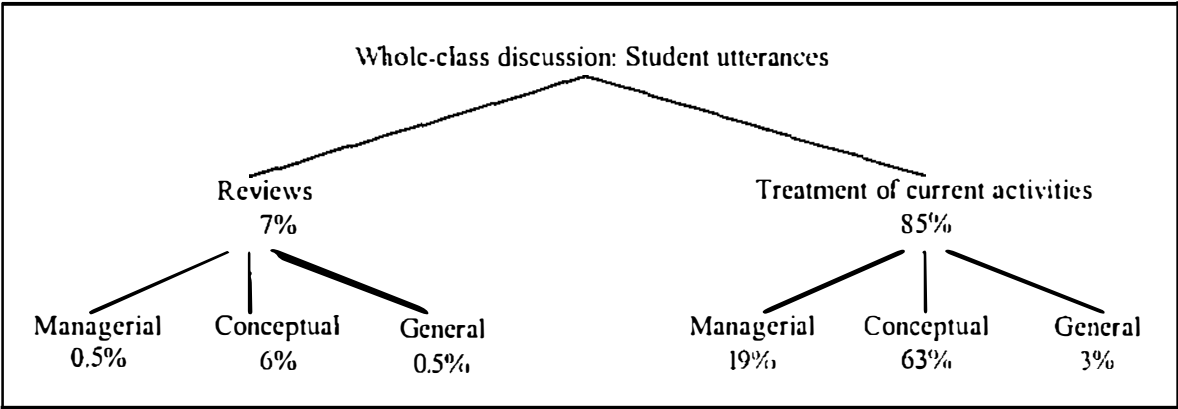
Ms Brown's students showed little interest in the review discussions and were often talking or using the materials if they were available. Usually the knowledgeable students were questioned and, when students with less understanding were questioned, it was apparent that they had not been listening attentively:

Ms Brown *Could somebody repeat what Paul's just said? Perhaps you, Jane.*
Jane *Um.*
Ms Brown *What were the parts that actually moved around the circuit. They were called the*
Jane *Electrons.*
Ms Brown *Electrons. And what did they pick up as they went through the battery?*
Jane *Energy*
Ms Brown *They picked up the energy. And as the energy was taken from the battery where did the energy go? What was the energy used for?*
Lucy *Lucy?*
Lucy *The globe.*
Ms Brown *To light*
Lucy *The globe up.*
Ms Brown *Okay, to make the globe light up. So eventually as the energy of the battery was disappeared the globe would go the battery would go flat.*

(Lesson 2)

The answers that students offered were often limited and Ms Brown had to question them at length to obtain complete answers. In this example, the lack of a cohesive response with no summary from the teacher may have resulted in limited understanding by the students.

There were only a small number of managerial comments by the students during the review time and these were mostly related to the discussions about the Summary Sheet when this provided the basis for the review. There was one closed question when a student was clarifying Ms Brown's question and the remainder of student utterances were all responses to closed questions (Figure 5.4).



N.B. A further 8% of comments were unintelligible

Figure 5.4. Use of whole-class discussion time: Student utterances

Treatment of current activities

The remaining whole-class discussion time, 92%, was used to discuss current work and the remaining 96% of Ms Brown's utterances and 85% of student utterances related to the treatment of current work. Fifty-four percent of Ms Brown's utterances related to management, either of the class or the task (Figure 5.3).

Teacher and class interactions

Ms Brown tended to direct the students in the tasks rather than allowing them to follow the written instructions and students did not move on to a new activity until directed. This resulted in a high level of task management utterances:

Ms Brown Right. In this lesson you're going to use and it'll be a little bit of repetition from what you did last week. You're going to make a circuit. But this time you're going to use the globe holder because that will be important because we're going to try different sized globes eventually. When we start off the globe you're to use is the smallest globe. You're going to need to make the uh circuit using the a strong elastic band

around the battery so that you can actually clip the bulldog clips or the alligator clips rather on to the battery. So you're going to use the wires which have the alligator clips. Okay. And you'll clip the alligator clips on to either end of the battery and then either side of the globe so that your circuit is. All right then. I'd like you, and you notice that in your diagram you have two wires on one side which are connected clipped together
(Lesson 2)

Often, when a student read out the instructions from the worksheet, Ms Brown repeated them. In Lessons 3 and 4, Ms Brown structured the class so that all students had a turn at constructing and the instructions were given step-by-step. During the discussion intended to develop understandings, six percent of the utterances were teacher explanations. Ms Brown's explanations varied in quality, with some being clear but others were often fragmented because of the control problems. She also, possibly because of the acoustics in the room and the constant talking by the students, often could not hear what the students said, further fragmenting the explanations. Twenty-three percent of utterances were closed questions and often related to the construction of the circuits or the results that were observed, rather than developing conceptual understandings, with the answers from the students generally short. A further 3% of the utterances were open questions where the students were expected to generate ideas (Table 5.2). However, over half of the open questions asked the students to predict what might happen and these were not followed-up in subsequent discussion.

<i>Ms Brown</i>	<i>Okay, I want you to make a prediction for me now I want you to predict what will happen if you use one battery. You've seen what happens with your 1.2 globe then you can use the next size globe and then the next size globe. What do you think will happen as you increase the size of the globe? Who can predict? Eric.</i>
<i>Eric</i>	<i>It uses more energy and gives out a greater light.</i>
<i>Ms Brown</i>	<i>You think it'll use more energy and give out a greater light if you increase the size of the globe.</i>
<i>Student</i>	<i>Yeah because it can take in more *** energy.</i>
<i>Ms Brown</i>	<i>That's an interesting idea. Who who agrees with Eric? Thinks the globes are going to be brighter as you increase the size of the globe? Okay. Who has another theory? What's your theory Greg?</i>
<i>Greg</i>	<i>The light will grow dimmer.</i>
<i>Ms Brown</i>	<i>You think the light will grow dimmer and I think you've had a little experiment there too. Why do you think the light's going to go dimmer?</i>
<i>Greg</i>	<i>Um * the electricity as it travels through and the ** smaller globe Um has more electricity *all the light energy so bigger globe will go dimmer.</i> (Lesson 2)

Ms Brown's tone of voice and wording in her response to the first answer indicated that it was probably not right and all the students' responses after this followed the pattern set by Greg with Ms Brown positively evaluating the responses. There was no discussion after the investigation to reinforce the understanding with only the brightness of the globe commented on.

Generally, when questioning, Ms Brown did not accept a variety of answers but discontinued questioning after the first correct answer. Ms Brown's questioning provided no indication that she was aware of the possibility of alternative frameworks.

Ms Brown used few teaching aids, with blackboard diagrams drawn by the students providing a basis for some of the discussion, although this often did not develop any understandings or the understandings were not strongly reinforced. In Lesson 3 students drew diagrams of series circuits containing two batteries on the board:

Ms Brown *Right. Thanks Lucy. And that worked quite well did it?*

Lucy *Yes.*

Ms Brown *Thank you. Okay, how many people had a circuit like Lucy's where you had connecting to a negative and then the next wire connecting to the positive and to the negative of the next battery? The wire in between the two batteries right around. Who had that one? Okay. (Lesson 3)*

A further student drew a diagram with no discussion at all about his circuit. Ms Brown followed this up by asking the students what happened when batteries were joined with the two negative or two positive terminals together. Later in the lesson diagrams with three batteries in series were drawn on the blackboard with no conceptual discussion.

The only teacher demonstrations were the two using the ammeters. On both occasions there were some limitations in Ms Brown's explanations. The first demonstration showed that the amount of current in the two wires of a circuit were the same. Although Ms Brown's ammeter readings were incorrect, her explanation and questions indicated this. However, there was only limited emphasis on the current passing through the globe and, as the class was inattentive, those students with a bipolar view of current flow may have only focussed on the readings, which may have reinforced their view.

On the second occasion the batteries connected to the ammeter were connected in parallel. The students were attempting to complete Summary Sheet 4 on which Ms Brown had placed restrictions as to the changes they could make and made the problem impossible to solve. During the course of the demonstration, Ms Brown recognised that

she had made the problem unsolvable. She talked through the development of her understandings as she did the demonstration:

Ms Brown With this ammeter, it shows you the amount of power going through the circuit. Now, at present I have two batteries connected and I have the right amount of power coming. With this ammeter it shows you the amount of power going through the circuit. Now, at present I have two batteries connected and I have the right amount of power coming through to light up that and it's two, just over the two two hundred um amps. Okay. If I disconnect this other battery did you notice the needles change at all? So it's still the same amount of power coming through and perhaps if I swap over, just wondering if I can take this other battery out, take this one out. (Pause) So it doesn't matter which battery I disconnect I still end up with the same amount of power. If I've got two batteries connected up in parallel the same amount of power comes through the circuit. The same amount of energy comes through the circuit. If I disconnect the first battery, the amount of energy coming through the circuit's the same. If I disconnect the second battery the er same amount of circuit coming through the through the cir the same amount of energy comes through the circuit. I wonder here, do you think you might need to add another battery to make it work longer? (Lesson 4)

However, the students may not have understood what was happening as a comment from the most knowledgeable student in the Focus Group indicated:

Neil What's this got to do with it? (Lesson 4)

Ms Brown covered all the practical activities that were in the lesson outlines, but rarely added any extra conceptual information. Her rather limited knowledge meant that, on the few occasions when the students extended their work, she needed to ask for help in assessing what had been done.

Student participation

Students generally found it hard to remain on-task and attentive during Ms Brown's discussions and demonstrated little enthusiasm. They were asked to turn around but some students turned back to their desks shortly into the discussions.

The percentage of student utterances in the general whole-class discussion was similar to Ms Brown's, with 8% of them not understandable (Figure 5.4). They contained a high proportion of responses to closed questions (46%) and a high number of questions clarifying the task (18%) (Table 5.2).

During this discussion time the students tended to be talking or using the equipment, particularly during the blackboard drawing by students. When asked to

respond their answers were limited and offered only the information that was requested. They did not extend their answers, limiting the understanding Ms Brown would have of their ideas. They rarely commented on or added to other students' answers and were not involved in constructing explanations. They only asked procedural questions and did not offer suggestions or ideas.

Table 5.2
Interactions Between Ms Brown and Students in Whole-class Discussions

Type of utterance	Review		Treating current activities	
	Percentage of utterances from:			
	Ms Brown	Students	Ms Brown	Students
Managing class or group	0.5		22	1
Managing equipment			3	
Managing task	1	0.5	29	18
Explanations	0.5		6	
Open questions			3	
Responses to open questions				12
Closed questions	2		23	1
Responses to closed questions		6	1	46
Information from students (conceptual)				3
Task management (conceptual)			8	1
Unintelligible				8
Other		0.5	1	3

Most of Ms Brown’s utterances were related to management with 8% involving some conceptual component. There were very few open questions but the next highest amount of utterances was closed questions. The students were also involved in many management utterances but the highest category for students was responses to questions, both open and closed (Table 5.2).

Use and Understanding of Scientific Vocabulary

Introduction

Ms Brown used a variety of scientific terms during the lessons, but they were often used only within the lesson teaching that particular concept. The students used few of the new terms, although the everyday words such as battery and globe were used frequently.

Ms Brown's use and explanation of scientific vocabulary

Ms Brown used a mixture of scientific and non-scientific terms with often only limited explanation of the terms. Words and phrases frequently used by Ms Brown were the common terms of battery, globe and wires; and the less common terms of circuit, energy, positive and negative. Her limited use of words across lessons is demonstrated by her use of the term 'electron', used frequently in Lesson 1, three times during the review in Lesson 2 and not used again, and the terms 'conductor' and 'insulator' used only in Lesson 2. She also frequently used the non-scientific term 'power' during the later lessons.

Some words, particularly the everyday words such as globe and battery, were not explained, although explanations may have improved the students' understanding of circuits and current flow. However, other less common words such as circuit and electric current, were also not explained.

The level of explanation varied. The explanation of some terms was very limited such as those for electrons and energy which were incidental:

Ms Brown Okay we're going to use some students who are going to be the electrons and this is the electricity'. (Lesson 1, before the role-play)

Ms Brown As the electrons move through the battery they gather energy and you're going to give each person a parcel of energy as they pass. Right, and they are going to carry that ... But when you get to Eric the electrons are going to pass some of the energy to Eric so that he has the energy. If he was really a globe he would light up. (Lesson 1)

Sometimes the explanations were built up during discussions and this was the case with the terms 'conductors' and 'insulators':

Ms Brown Who has made their circuit work by just touching the drawing pins. Okay.

Ms Brown What does that tell you about the drawing pins? Yes, Lucy?

Lucy It means that the metal they're made of conducts electricity.

Ms Brown Right the important word was it is a conductor. Just like the alligator clips also are conductors. Now separate the drawing pins so that there's about a 2 centimetre gap between them. Okay

Ms Brown What do you notice happens? What do you notice happens? Joan?

Joan It doesn't work

Ms Brown All right what does it tell you about the styrene foam then? Yes?

Student It's not a conductor. (Lesson 2)

Ms Brown then went on to generate the word that meant the opposite of conductor.

Several of Ms Brown's explanations needed to be clearer to ensure the students understood, such as those for series and parallel circuits:

Ms Brown Because you put the batteries you had to construct them in some way so that they ran in order So that you had positive to negative and so on in that particular circuit and that is called a series circuit. (Lesson 3)

Ms Brown With the parallel circuit you are able to put in extra globes still with the one battery but you're able to retain the amount of energy going through and you can actually add another globe to that circuit. (Lesson 4a)

Student use of scientific vocabulary

Students in Ms Brown's class used the common terms of battery and globes frequently with the less common terms of circuit and volts also often used, mainly as descriptors. Positive and negative were used often as was energy, with conductor and insulator used infrequently, although Ms Brown did not use these to any great extent either. There were no words that Ms Brown used that the students did not use although some, such as electric current or current were used rarely.

Mr Carter

Classroom Management

Mr Carter had a friendly attitude towards his class and often called the students by nicknames during discussions. The class tended to be noisy and Mr Carter frequently needed to bring them back on task during discussions. However, it was often the same students who were distracted and talking. He often stopped what he was saying and interrupted the discussion but the interruption was usually only a one sentence comment, and he would immediately get back to the discussion:

Mr Carter Kids, it's important please that you use. No I'm I'm just not getting any cooperation at all. Thank you. It is important that you use the equipment that I ask you to use and nothing else ... I promise we will get on to using almost everything in your kit, otherwise it wouldn't be there. (Lesson 1)

His management comments were often light-hearted, but he could be firmer.

Materials were nearly always on the desks during discussions or demonstrations and provided a distraction for the students. The students were sometimes moved to the front of the class for demonstrations but usually they remained at their desks and, for these and discussions, were asked to turn around. The students tended to turn their heads only and turn back to their desks after the discussion was under way.

Mr Carter was the only teacher who commented positively to the whole-class:

Mr Carter I was very, very impressed with the wind up session. Most groups got on and really did discuss this afternoon this end session, particularly the back two groups, they both did a fantastic job. (Lesson 1)

He was also the only teacher in the study who, prior to the initial activities, discussed safety aspects.

Whole-class Discussions

Although there was some off-task behaviour, it was limited as his discussions were animated and fast and often diverted into areas other than those specified. He usually called on a range of students for answers but also sometimes aimed the questions at two knowledgeable students. Some students were occasionally willing to argue points and ask for information outside that covered in the lesson content. When ways that a simple circuit could be connected had been suggested, one student felt that two circuits were the same:

Student That's just the same as having the globe on the negative end.

Mr Carter Is it?

Student The wire on the hump of the globe goes down into negative so instead of having the um wire on the er screw part of it, you have it on the bottom and it connects to the negative, so it's the same the same thing. (Lesson 1)

A few students also occasionally showed evidence of extended thinking. Because of limitations in the equipment, Mr Carter was unable to offer a way of constructing a circuit suggested by a student but another student worked it out:

Student Just twist two ends of the wire together. (Lesson 1)

Mr Carter sometimes used practical demonstrations and student models to help explain concepts with students sometimes moving to the front to see demonstrations and others held at the front of a seated class. He also used blackboard diagrams, a limited number drawn by students whilst the class was watching and others quickly drawn by himself. Students were often required to evaluate or correct the diagrams. Because of the limited number drawn by students, the watchers were usually attentive. Apart from responding to the teacher's questions, the students were not usually involved in demonstrations, but were involved in the role-plays that Mr Carter instigated. He was an effective user of analogies. The structure of his discussions ensured that students had

substantial input with effective use of open and closed questions. The science equipment was left on the desks during discussions but the students, although not always turned to face Mr Carter, were generally involved in the discussion.

Interactions and Use of Time in Lessons

This section examines the types of interactions that occurred in whole-class discussions; the way the time was used; and the use and explanation of scientific and non-scientific vocabulary.

Types of interactions during whole-class discussion

Fifty-five percent of the total lesson time was used for whole-class discussions including task and class management. It was used for two broad purposes; reviewing previous work, and treating current activities. Mr Carter used different types of interactions during this time including open questioning where students, rather than presenting factual, correct answers, were expected to think and produce a variety of explanations; closed questioning, where once the factual correct answer was found the teacher moved to a new question; and teacher exposition where Mr Carter dominated the interactions, usually describing and explaining, sometimes using analogies and incorporating role-play by the students. After constructing a series circuit which included a reversed battery, Mr Carter used role-play to explain what was happening:

- Mr Carter* *If you can imagine you got a big railway engine here Diane be a railway engine coming the other way.*
- Mr Carter* *Here, hop on this railway line.*
- Mr Carter* *We're both the same size. Here comes the railway engine. You've got to come this way because you're a railway engine. What happens when we meet in the middle?*
- Mr Carter* *No, you can't get off the railway line yet *. Come on railway engine. No, no, no. You've got to come this way because that's the way your engine's going. What happens when we meet here?*
- Student* *Stop.*
- Mr Carter* *What happens?*
- Student* *Collide.*
- Mr Carter* *You stop. Does the. Does one keep going?*
- Students* *No.*
- Mr Carter* *So what's going to happen in here?* (referring to circuit diagram on blackboard) *It will?*
- Students* *Stop.*
- Mr Carter* *Stop. Okay. (Lesson 4)*

An analysis of the interactions shows that 69% were made by Mr Carter and 31% by the students. Generally, Mr Carter's utterances were longer than those of the students.

Reviews

Mr Carter spent 13% of the discussion time reviewing work completed in that or previous lessons (Figure 5.5). Ten percent of Mr Carter's utterances and 12% of student utterances were related to reviewing previous work (Figures 5.5, 5.6).

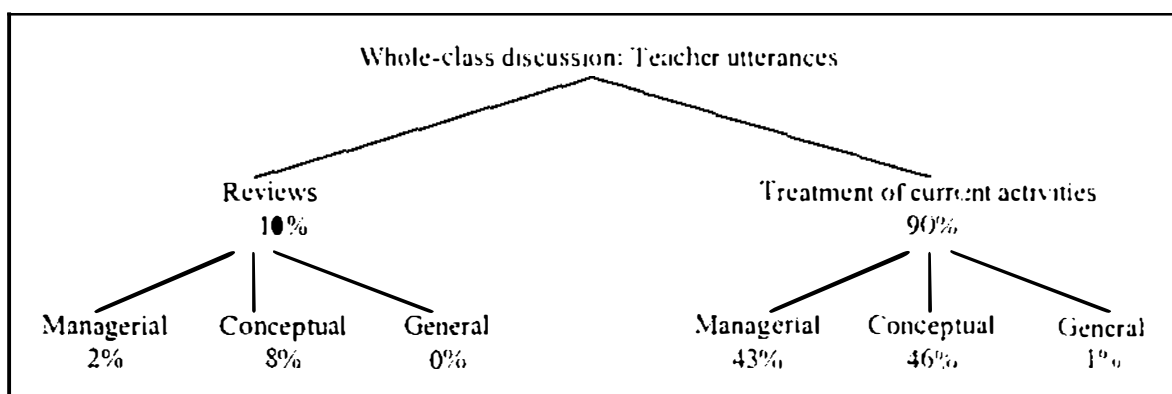


Figure 5.5 Use of whole-class discussion time: Teacher utterances

Mr Carter reviewed at the beginning of the second and third lessons: at the beginning and end of the fourth lesson and often incidentally during the lessons. He also allowed time at the end of all the lessons for the groups to discuss what they had been doing although he did not usually elicit and check the ideas that the students were generating in a whole-class discussion and, as he did not visit all the groups, there was no guarantee that the ideas they generated were correct. Generally, during the review time the students, although not turned round in their seats, were attentive. The science equipment was on the desks during the whole-class reviews but had usually been packed away by the time the groups were discussing the focus questions. In the reviews at the beginning of the lessons Mr Carter asked the students what they had learnt so far in electricity. This resulted in a discussion which followed the answers that students offered and some concepts were not reviewed in any detail. Usually Mr Carter pursued the answers to extend the ideas being explained:

Mr Carter *What's one of the important terms that we've come up with?*
Student *A circuit.*
Mr Carter *A circuit. Explain to me what a circuit is. What's a circuit. Scott?*
Scott *It's a, it's a thing that has a battery and wires and runs from the positive through the wires up to a globe and out the globe to the negative.*

Mr Carter *Okay. That's not a bad go. Peter?*
Peter *A circuit is something which electricity can just go round and round.*
Mr Carter *Mm, mm. Allen?*
Allen *Um, a circle of components. (Lesson 2)*

Three percent of Mr Carter's utterances were explanatory and 4% closed questions, although he did ask a few open questions (Table 5.3). However, the class tended to be very involved in the reviews because of the nature of Mr Carter's discussions and, although he often questioned at length, he usually summarised the answers that he had obtained from the students to close the discussion:

Mr Carter *Okay. What do we need to make the electricity work? We need something to make the electricity work. We don't need a real technical answer. We just need well one word. James?*
James *A circuit.*
Mr Carter *A circuit. Is that a circuit if it just comes out there and stops there? (Demonstrates with equipment)*
Students *No.*
Mr Carter *What about if I hold it up there? Get a longer piece of?*
Students *No.*
Mr Carter *I mean I can make it as long as I like, when's it going to be a circuit? When's it going to be a circuit? Jenny.*
Jenny *When another wire ** of it.*
Mr Carter *So I put a wire here. My battery's just there, I've got a wire coming out here over to my globe. Put a wire on that end throw it over there to Leigh.*
Student *No, um.*
Student *When the globe touches.*
Mr Carter *So when the globe touches here. Okay, when else might it be circuit? I agree by the way, but when else can I make a simple circuit? A very simple circuit. Roger.*
Roger *When all the pieces are joined. When all the pieces are joined.*
Mr Carter *When all the pieces are joined. Okay. What would be my simplest circuit? My simplest circuit? Allen?*
Allen *Having a wire to the bottom of the globe and then the other the silver part or the other bit of globe to the top of the battery.*
Mr Carter *Yeah. If I just had my battery wire out to my globe, globe sitting, providing the wire's not touching the brass button. I've got the brass part touching the battery it's got to go to the end. Okay. Providing the wires going to the end and the brass part's on the positive terminal or the zinc's on the terminal and the wires on the edge. (Lesson 1)*

Mr Carter frequently reviewed ideas incidentally and on some occasions the review sessions turned into a teaching-learning sessions:

- Mr Carter* Tell me what will happen, Geoff, the man of experience, what will happen if you put join more than one of those big batteries with the little globe?
- Geoff* It'll blow.
- Mr Carter* It'll blow. What does that mean? I'm sorry.
- Geoff* It'll not work any more. It'll not work any more.
- Mr Carter* It's a term we use all the time isn't it? Oh, that globe's blown. What do we really mean by it?
- Student* That it's just gone out.
- Mr Carter* It's gone out. But if I go over and switch this switch over here the lights will go out, well these will come on. Come on what does it really mean? Gemma?
- Gemma* That there's no electrical current flowing through * it *.
- Mr Carter* But these ones haven't got an electric current flowing through them and you wouldn't say these are blown. Colin?
- Colin* It's broken
- Mr Carter* What's broken?
- Colin* The light globe. The little *.
- Mr Carter* Whereabouts is it normally broken? Fi?
- Fiona* The little filament thing *.
- Mr Carter* Good girl. It's a little filament broken. And what's that done?
- Fiona* It means that the light can't pass through it and make.
- Mr Carter* Well, when the filament breaks you know you've got a light he said as he looked for his chalk. Here we go. (Mr Carter drew on blackboard) Okay normal bulb something like that and it's got (drawing) Right? If this breaks (erases part of the filament) What's it done? What has actually happened? Renae.
- Renae* It's broken the circuit.
- Mr Carter* Good girl. It's broken the circuit so it won't work. (Lesson 3)

Apart from using the focus questions from the lessons to direct group discussion, they were not used by Mr Carter and, because the reviews were directed by the students' responses, some concepts were not covered. Students who were absent did not have the opportunity to find out what happened the previous week, and other students had less opportunity to develop understandings.

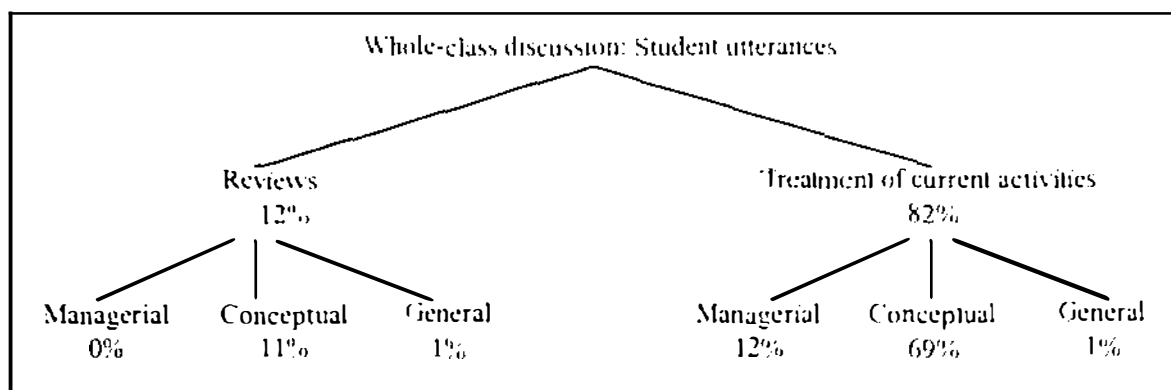
Student participation in reviews

Most of the students were reasonably attentive during the review sessions and became involved in the discussions. The students were mainly involved in responding to closed questions (9%) during the review time although a small number of responses (1%) were to open questions. However they were expected to justify their answers. A

small amount (1%) of conceptual type information was also offered, usually in the form of explanations of the circuits they had constructed or observations they had made:

Student *Um. It doesn't work if one touching the brass but and one touching the *.*
(Lesson 1)

Students sometimes commented on or reacted to other students' comments and were willing to respond to Mr Carter's ideas. His method of questioning resulted in the students often being involved in constructing explanations.



N.B. A further 6% of student comments were unintelligible

Figure 5.6 Use of whole-class discussion time: Student utterances

Treatment of current activities

The remaining 81% of discussion time was used to examine current activities (Figure 5.5). Ninety percent of Mr Carter's utterances and 82% of student utterances during the whole-class discussion time were related to treating current activities of which 43% of Mr Carter's comments were related to management (Figures 5.5, 5.6). Twenty-three percent were task management with the remaining related to class management. Forty-six percent of utterances related to the development of understandings.

Teacher and class interactions

Mr Carter sometimes used the instructions that were written on the sheets, but often changed them, either to encourage the students to think and discuss before they did an activity, or to make the task open-ended. He sometimes extended the activity:

Mr Carter *I want you to work out a common property of those (insulators). A common property of those (conductors). What's common about these one two three four five six? What's common about one two three four five? I want you to work out one common factor for these six and another common factor not the same common factor for both ...* (Lesson 2)

Where the discussion was intended to develop understanding, 19% of the utterances were teacher explanations, which were generally clear and involved the students in developing the explanations. Twenty-six percent were questions with 6% open and 20% closed (Table 5.3).

Mr Carter also usually ensured a variety of answers were obtained before confirming the correct response and, although his responses were not neutral, they did not indicate the correct answer initially. When he was demonstrating a circuit containing ammeters for the first time, the circuit was connected except the globe was loose. The students were asked to suggest why the globe was not lighting and, although the correct answer was obtained in the second response, Mr Carter encouraged more answers before stating the correct one.

Often, the structure of the discussions enabled students to be involved and encouraged them to think:

<i>Mr Carter</i>	<i>Okay. So explain to me how the circuit works. Start with this battery here.</i>
<i>Student</i>	<i>Energy goes through the battery.</i>
<i>Mr Carter</i>	<i>Sh sh. Carrie's going to do it.</i>
<i>Carol</i>	<i>Okay. * the battery all the batteries um all facing the one the same way.</i>
<i>Mr Carter</i>	<i>Okay.</i>
<i>Carol</i>	<i>**</i>
<i>Mr Carter</i>	<i>Good girl. So where's one wire going from, Carol, to?</i>
<i>Carol</i>	<i>One battery to another.</i>
<i>Mr Carter</i>	<i>But what part of the battery's it going from?</i>
<i>Carol</i>	<i>It goes from positive to negative.</i>
<i>Mr Carter</i>	<i>It goes from the positive to the negative through the battery out the other end from the positive to the</i>
<i>Students</i>	<i>Negative. (Lesson 3)</i>

Although Mr Carter needed to question to get a full answer, he did summarise the response, using a diagram to show the flow of current.

The students were frequently asked to suggest ways of solving the problems they had been set or to predict what might happen when an action was taken with Mr Carter then following up the results. When the students had a circuit set up with three batteries in parallel, Mr Carter extended the activity:

<i>Mr Carter</i>	<i>If you turned the second battery around, Derek's got his so that the positive's up this end, negative's up that end, if we turn that globe (sic) around, what do you think would happen. Sh. You're not allowed to do it yet.</i>
------------------	--

Student *It'll stop working.*
Mr Carter *Sh. Stop working?*
Student *The globe'll go out.*
Mr Carter *No, you've just done it. I don't want to hear from you. I want to hear from people who are doing it the honest way.*
Mr Carter *Em. What do you think will happen?*
Emily *I think that it um will go out.*
Mr Carter *Why?*
Emily *Because.*
Mr Carter *You think it will go out. Why do you think it will go out?*
Mr Carter *Come back to you. Don't stop thinking. Think. Come on. Somebody else. What's your prediction, Roger?*
Roger *It'll go really dull. It'll go really dull because.*
Mr Carter *It'll go really dull Why do you think it'll go really dull?*
Roger *Because there's still some * energy then but it's not very *.*
The students then did the activity and the ensuing discussion looked at what happened:
Mr Carter *What do you think the problem there might be then.*
Student *** the circuit **.*
Mr Carter *What's the problem What's the what's the problem in the circuit.*
Student *That we haven't got the wires fixed properly.*
Mr Carter *Good girl. They're not. The wires probably aren't working as well as they should be Leigh?*
Leigh *** battery **.*
Mr Carter *So. All the energy that's coming that way and back around here What's this battery do when we turn it round positive to negative?*
Mr Carter *Okay. Remember that's coming (drawing on board) that way, isn't it? Well, up via the globe. What's the energy from this battery trying to do, Terry?*
Terry *Go the other way.*
Mr Carter *Go the other way, and what's going to happen when things two things go the opposite way?*
Student *They're just going to stop each other.*
Mr Carter *They stop each other (Lesson 4)*

Mr Carter then used the railway engine analogy previously described. He also used relevant models, both his and the students', and blackboard drawings to help the students understand the concepts, with explanations that were usually clear. Students were sometimes called to the front of the class for demonstrations, but were often at their desks where the materials tended to distract them. He often used a strategy with which the students appeared familiar where, once an explanation had been developed, he would ask the students to give him a 'therefore statement'. This encouraged the students to think about their explanations and justify them or develop them further:

Mr Carter *Rightyo then. Thank you. Shh. Who can tell me a common property of all insulators? All the insulators? What's a common property of the insulators?... Peter?*

Peter *They're non metallic*

Mr Carter *They're non metallic, therefore. Give me a statement. Therefore?*

Student *Electricity won't flow through them.*

Mr Carter *Electricity won't flow through them. Fair enough. What else? Therefore, what else? Come on, give me a few therefore statements.*

Student *Therefore the energy doesn't pass **. Therefore the energy doesn't pass through it.*

Mr Carter *Therefore the energy doesn't pass through it. Fair enough.*

Roger *Therefore if you put it in a circuit it will break it.*

Mr Carter *If, I like this one. Therefore, if you put it in a circuit it will break the circuit. Well done, Roger. Allen.*

Allen *Therefore there aren't enough electrons in it.*

Mr Carter *Therefore there aren't enough electrons in insulators. Fair enough.*

(Lesson 2)

The supplied posters were on display both in Mr Carter's classroom and in the room where the science lessons were held but Mr Carter did not refer to them.

It is apparent from the examples that Mr Carter used his knowledge of electric circuits to extend the discussion into areas other than those in the lesson outlines, but the limitations of his knowledge also allowed him to accept answers from the students that were unscientific, possibly because they were difficult to understand. He demonstrated a lack of knowledge of alternative frameworks with some of his responses. He did not include all the activities from the lesson outlines and did not address all of the focus questions.

Student participation

Generally the students were attentive and interested in the discussions although some groups were easily distracted. Although asked to turn around, not all students did so, but most were engaged in the discussion.

Twelve percent of the student utterances were related to management with most (9%) being task management, usually responding to Mr Carter (Figure 5.6). There were a few comments which were unrelated to the topic and a further 6% where the recordings were unclear. The remaining 69% of utterances were related to discussion intended to develop understandings, of which 49% were responses to closed questions which often involved the students in explaining how their circuits were connected and sometimes how they worked with students often extending and justifying their answers (Table 5.3):

Student *We added another battery so that it would give us more energy so it would make the light glow. (Lesson 3)*

Fourteen percent of responses were to open questions (Table 5.3). There were a few questions from the students which were not procedural, mostly in the last lesson when students were discussing the whole-class investigation looking at how long different types of circuits would last:

Student *How come the one with one battery's gone bright and the ones ***?*

Colin *They were, were they all new batteries? (Lesson 4)*

There was also a small amount of information from the students, again mostly responding to comments by Mr Carter but sometimes bringing things to his attention.

Table 5.3

Interactions Between Mr Carter and Students in Whole-class Discussions

Type of utterance	Percentage of utterances from:			
	Review		Treating current activities	
	Mr Carter	Students	Mr Carter	Students
Managing class or group	1		20	2
Managing equipment				1
Managing task	1		23	9
Explanations	3		19	
Open questions	1		6	
Responses to open questions		1		14
Closed questions	4		20	2
Responses to closed questions		9	1	49
Information from students (conceptual)		1		4
Unintelligible		1		6
Other			1	1

Most of Mr Carter's utterances were related to management. However, there was also a high number of questions and explanations, with most questions being closed. The students utterances were mostly responses to questions, either open or closed, with a small number related to management (Table 5.3).

Use and Understanding of Scientific Vocabulary

Although Mr Carter used a variety of scientific terms in discussions, the students tended to use few of the new scientific terms themselves, although the everyday words

which referred to objects rather than concepts, such as battery, globe and wires were used more frequently.

Mr Carter's use of scientific vocabulary

Mr Carter used a mixture of scientific and non-scientific vocabulary offering explanation for some words and not for others. The explanations were often part of the general discussion with Mr Carter sometimes encouraging the students to generate their own explanations. Words that were most frequently used by Mr Carter were battery, circuit and globe, with many other words being used frequently during the lesson in which the concept was discussed and infrequently apart from that. There were some words that were not explained including commonly used words such as globe and battery, where explanations may have improved student understanding of circuits and current flow. Other less common words such as electric current and electrons were also not explained.

Some explanations were very limited. Although the students had constructed circuits with batteries and globes in series and parallel there was no explanation of the terms and the circuits were merely drawn and named at the end of Lesson 4.

Sometimes Mr Carter's explanation were incorrect:

- Mr Carter* *So what can you tell me about these electrons that are going through the wrong way?*
- Student* *It slows them down.*
- Mr Carter* *It just slows them down. Are they creating as much energy to get to the light? Are the electrons, Jenny, creating the same amount of energy to go to the light? (Lesson 3)*

Mr Carter rarely gave an explanation, they were generally included in the discussion or generated during questioning of students, with Mr Carter reinforcing the meaning by questioning.

- Peter* *Because the foam's an insulator not a conductor.*
- Mr Carter* *Shh. Peter's just introduced a couple of big words. Peter what have we done?*
- Peter* *The foam's not the foam's a insulator not a conductor.*
- Mr Carter* *The foam is an insulator. Foam isn't What isn't it?*
- Peter* *Conductor. (Lesson 2)*

Further discussion elaborated on the meanings of the terms 'conductor' and 'insulator'.

Student use of scientific vocabulary

Students in this class used the common words of battery and globe frequently, but also used the less common words of circuit and energy often. Positive and negative and conductor and insulator were used fairly frequently with most other terms rarely used. Terminals was used by Mr Carter and not the students as was series circuit but, since this name was only introduced at the end of Lesson 4, the students did not get an opportunity to use it.

Discussion

The Teachers' Management of and Strategies Used During Whole- Class Discussions

Whole-class interactions need to consist of teacher-class interactions in the form of discussions which allow students to demonstrate their understandings and allow the teacher to help students move towards more scientific understandings (Solomon, 1989).

The amount of time spent on whole-class activities was very similar between the three teachers. However, Mr Avery used considerably more of the discussion time to review work than either Ms Brown or Mr Carter. In all of the discussions the teachers dominated the interactions. No studies have been found that examine the breakdown of time usage in primary science lessons but constructivist approaches to science teaching (eg. Cosgrove & Osborne, 1985a, 1985b; Driver et al., 1994) indicate that the whole-class discussion component of the learning is needed to ensure students become aware of other understandings and are introduced to new ideas. All three teachers engaged in whole-class discussion using the time in different ways. However, overall the amount of management interactions during whole-class discussions tended to take up about half of the whole-class discussion time, with Ms Brown using more than half the lesson time and both Mr Avery and Mr Carter slightly less than half resulting in them having about 10% more interactions related to conceptual matters than Ms Brown.

Assertion 5/1

Approximately half of the interactions in primary science lessons of the type studied, relate to management of the task or of student behaviour.

The three teachers' class and discussion management was very different. Both Mr Avery and Mr Carter had a friendly relationship with the students whereas Ms

Brown tended to be more formal in her interactions both with the whole class and with groups. Fraser (1991) stated that students preferred a more positive classroom environment and this was demonstrated by the willingness of the students in both Mr Avery's and Mr Carter's classes to participate. They were also confident enough to make suggestions and were willing to argue with the teachers, albeit in a friendly manner. This gave the students more opportunity to actively participate in constructing personal explanations and increased their level of interest (Driver et al., 1989; Pintrich, 1993; Villani, 1992). Caravita and Halldén (1994) and Driver and Oldham (1986) emphasised the need for a supportive classroom environment and Pintrich et al. (1993) felt that often the social/affective domain of classrooms is not taken into consideration when looking at learning.

Assertion 5/2

When the classroom is friendly, students are more likely to participate fully in both the discussions and activities, offering ideas and suggestions and questioning the teacher's statements.

Mr Carter was the only teacher who gave his students whole-class positive feedback. This occurred mainly in the first two lessons and less in the third and fourth but he also showed interest in the students' ideas and enthusiasm at their successes. Neither Mr Avery nor Ms Brown offered any whole-class positive feedback but Mr Avery constantly showed enthusiasm for and commented on students' successes and ideas. Both Mr Avery and Mr Carter's students often showed the teachers their successes and offered suggestions. This resulted in more individual feedback than was available in Ms Brown's class and more opportunities for the students to make personal sense of the work. This supports Assertion 5/1 but also introduces Assertion 5/3.

Assertion 5/3

Student enthusiasm may be increased by the teacher's willingness to listen to and comment on students' successes and ideas either in whole-class or individual settings.

In all classes the instructions for the activities were given prior to the students' group work during the whole-class discussion time. In Mr Avery's class the instructions were usually read by a student with Mr Avery then expecting the students to continue

with the task by referring to the worksheets. The instructions were also read by a student in Ms Brown's class with Ms Brown then repeating the instructions. Mr Carter restructured the instructions to make the tasks more open-ended giving the class oral instructions for the revised task. Mr Avery's method of organising the activities allowed the students some responsibility for their work, as did Mr Carter's. However, Ms Brown's method resulted in the students relying on her for all instructions.

Assertion 5/4

A variety of methods can be used to provide instructions for activities, some of which are imposed and some of which allow students to exercise independence.

Mr Avery and Mr Carter tended to use low-key incidental control mechanisms for poor behaviour which avoided interrupting the flow of the lesson to any great extent but which still gained the attention of the miscreant. Both, on occasion, used stronger methods but the interruption to the lesson was usually brief, with the teacher talking to the student later. Ms Brown's behaviour management was more intrusive and usually the whole class was involved in any reprimand. This often stopped the lesson and fragmented the discussion or activity. This may have affected any learning that might occur as Berliner and Rosenshine (1977) considered that primary students would have difficulty learning when lessons were disjointed.

Assertion 5/5

Less intrusive use of control strategies helps to ensure that lesson flow is maintained.

Class discussions require the attention of the students and their participation to encourage development of understandings (Driver et al., 1994; Pintrich, 1993). During the main whole-class discussions and demonstrations the students in Mr Avery's class were moved to face the teacher, physically moving their chairs around. In the other two classes the students were asked to turn round but usually only turned their heads and often turned back part the way through the discussion. This was particularly prevalent in Ms Brown's class. Students in Mr Avery's class were less likely to talk or be distracted by items on the desk than those in the other classes, although students did sometimes use the materials.

Assertion 5/6

When students are moved to face the teacher during whole-class discussions, student attention and participation is improved.

In all the classes the equipment was packed away for the main reviews, although in Ms Brown and Mr Carter's class it was still on the desks although in a box. However, for incidental reviews and for much of the discussion treating current activities the equipment was usually out and tended to be a distraction for some students although less so in Mr Avery's class when the students were turned around in their chairs.

Assertion 5/7

When materials are not available during the discussions, student attention and participation is improved.

The atmosphere of the discussions was also very different. Mr Avery and Mr Carter involved the students in animated discussions although Mr Avery's discussions were quieter and not as fast paced as Mr Carter's. They also used a wide range of strategies to present information and ensured that a wide range of students participated, although Mr Carter sometimes focussed on the most knowledgeable students in the class. The students in Mr Avery and Mr Carter's classes were usually involved and paying attention. The discussions in Ms Brown's class tended to be slow paced and lack the interest that was generated by the other two teachers. She used few strategies to present the information to the class and a smaller range of students were asked to respond to questions, often those who would be likely to know the correct response. Gage and Berliner (1992) and Wilen (1987) felt that it was important that a variety of students were asked to respond, including those who were not volunteering. The tendency to call on high ability students was noted by Doyle and Carter (1987) and Gage and Berliner and it was considered that it was often used to obtain correct answers. However, this does not allow the teacher to become aware of different understandings that might be held by other students which is an important aspect of constructivist teaching (Cosgrove & Osborne, 1985b; Driver & Oldham, 1986).

Assertion 5/8

Animated whole-class discussion using a variety of strategies helps to maintain student interest and engagement.

Assertion 5/9

Obtaining responses from many different students helps to maintain student interest.

Assertion 5/10

Questioning a variety of students allows the teacher to become aware of the range of understandings held by the class.

Whole-class interactions may involve teacher explanations (Lemke, 1996; Ogborn et al., 1996), questioning (Anderson & Smith, 1987; Gall & Rhody, 1987), brainstorming (Solomon, 1989) and discussions (Gage & Berliner, 1992; Wilen, 1987) (1996). Gage and Berliner and Swift et al. (1988) stated that the review section of a lesson was more likely to include closed questions than open, although the reviews in the three classes studied also used some explanations. Oral questioning is an important aspect of teaching and learning (Gall & Rhody, 1987). All the teachers used a variety of questions and explanations in all discussion times, although Ms Brown's were rather more limited than the other teachers. They all used more closed questions than open (Cunningham, 1987) with Mr Avery and Mr Carter using more open questions than Ms Brown. Both Mr Avery and Mr Carter used some open questions during the review sessions as well as during the class discussions whereas Ms Brown tended to use more open questions when looking for predictions during the main discussions.

Assertion 5/11

A variety of types of questions elicits a wider range of responses from the students.

Mr Avery usually obtained a variety of responses to his open questions and then either engaged in a demonstration that showed the correct answer or, later in the lesson after further investigation, the correct answer was explained. Mr Carter sometimes did this but also sometimes only accepted one answer, usually when the first answer was correct. Ms Brown tended to accept the first correct answer, but did allow a variety of responses for predictions.

Assertion 5/12

Open questions may be used in many situations to generate ideas and discussion.

Ogborn et al. (1996) suggested that explanations are enhanced by the use of a variety of strategies, including demonstrations and the use of analogies. Mr Avery and Mr Carter used the suggested demonstrations and some of their own when conducting discussions during the review sessions or those treating current activities. They also used the circuits constructed by students; Mr Avery used them to help explain how circuits worked; and Mr Carter used them to demonstrate how particular circuits could be constructed. Using the students' circuits gave the student more opportunities to share their ideas (Cosgrove & Osborne, 1985b). Ms Brown did not use the actual circuits but asked the students to draw them on the blackboard and she only used two of the suggested demonstrations with no extra ones. She also did not use any demonstrations during the review sessions, only during those treating current activities.

Assertion 5/13

The use of a variety of teaching aids and diagrams on the blackboard or from posters, with clear explanations may assist in the development of scientifically acceptable understandings.

Smith and Neale (1989) felt that important segments of the curriculum materials may often be omitted by teachers with Arditoglou and Crawley (1990) suggesting that the teachers' understandings may change the curriculum writer's intentions. Mr Avery used the supplied diagrams frequently although the other teachers did not. All the teachers used the suggested role-play in Lesson 2. Mr Avery also used the suggested analogies and added some of his own and Mr Carter used his own analogies to help explain some his extension activities. Neither Ms Brown nor Mr Carter used the supplied analogies. The students in both Mr Avery and Mr Carter's classes were more likely to be involved and interested in the discussions.

Assertion 5/14

Information provided in curriculum materials may not be effectively used.

Assertion 5/15

When parts of a lesson are missed, teachers do not always recognise that they are omitting part of the curriculum and this will have a negative impact on learning.

Assertion 5/16

Using analogies helps students to relate abstract ideas to things that they understand and provides opportunities for learning.

Information about students' alternative frameworks in science has been available for many years (eg. Confrey, 1990; Gilbert et al., 1982; Webb, P., 1992). Of the three teachers, only Mr Avery demonstrated an understanding of these, with the other two teachers showing surprise at some of the responses made by the students, indicating a lack of or a limited knowledge of the understandings that students might hold.

Assertion 5/17

Some teachers demonstrate little knowledge of students' alternative frameworks.

Discussion in a science lesson frequently involves the use of terms with which the students may not be familiar or for which they have their own meaning. This results in information from the teachers being misinterpreted or partially understood (Bell & Freyberg, 1985; Lemke, 1990) All the teachers used and explained some of the scientific terms, with Mr Avery using a greater range of terms. The teachers generally did not use the terms consistently and this may have been lack of understanding on the part of Ms Brown and Mr Carter. However, Mr Avery, who was knowledgeable about electric circuits sometimes confused 'energy', 'electrons' and 'electric current'. Many of the terms used by the teachers were never explained and, although some of them were common terms, students' understandings were never checked.

Assertion 5/18

Teachers may not use scientific terms consistently.

Assertion 5/19

Teachers may not explain all of the scientific terms they use.

Summary

This initial group of assertions is based on teachers' behaviours that were consistently displayed during the whole-class discussions. Both Mr Avery and Mr Carter engaged in a variety of behaviours that might improve the students' opportunities to learn. Ms Brown had some behaviours that increased the learning opportunities, but also had practices that were likely to limit the learning that would occur (Figure 5.7).

Mr Avery	Ms Brown	Mr Carter
Just over half the lesson time used for whole-class discussion with nearly half this time used for management	Just over half the lesson time used for whole-class discussion with over half this time used for management	Just over half the lesson time used for whole-class discussion with nearly half this time used for management
More utterances from Mr Avery than from the students	More utterances from Ms Brown than from the students	More utterances from Mr Carter than from the students
Friendly to students	Distanced from students	Friendly to students
No whole-class positive feedback but teacher showed interest in and supported student successes and ideas	No whole-class positive feedback or individual recognition	Whole-class positive feedback and teacher showed interest in and supported student successes and ideas
Instructions given to whole class then students expected to work independently	Instructions read by student and then repeated by Ms Brown	Instructions for open-ended tasks given to whole class then students worked independently
Control incidental	Control interrupted discussions	Control incidental
Students turned their chairs around to face teacher	Students turned their heads but often turned back to desks during discussions	Students turned their heads but often turned back to desks during discussions
Equipment sometimes on desk but packed away for main discussions	Equipment always on desks but sometimes packed in box	Equipment usually on desks but sometimes packed in box
Quiet but animated discussion using a variety of strategies	Discussion not animated or interesting using limited strategies	Discussions fast and animated using a variety of strategies
Used posters, blackboard drawings, models, specified and extra practical demonstrations to help explanations	Used some specified practical demonstrations and some blackboard drawings to help explanations	Used blackboard drawings, role-plays, specified practical demonstrations, and models to help explanations
Discussion involved many students in the class	Discussion often involved the same students	Discussion involved many students in the class
Used good explanations with demonstrations	Explanations sometimes unclear to students	Used some good explanations with demonstrations
Used a variety of questions and explanations	Used a more limited range of questions and explanations	Used a variety of questions and explanations
Many closed questions (146)	Many closed questions (212)	Many closed questions (205)
Many open questions (99)	Fewer open questions (43)	Many open questions (72)
Often obtained a variety of answers before explaining correct answer	Accepted first correct answer	Sometimes accepted a variety of answers before explaining correct answer
Often expected and accepted a variety of answers	Often accepted first correct answer. Only accepted a variety of answers for predictions	Sometimes accepted a variety of answers, sometimes first correct answer

Mr Avery	Ms Brown	Mr Carter
Used student models to assist explanations	Used student models to demonstrate construction	Used student models to demonstrate construction
Used analogies effectively	Used no analogies	Used analogies effectively
Changed or omitted parts of the curriculum materials	Changed or omitted parts of the curriculum materials	Changed or omitted parts of the curriculum materials
Knowledgeable about students' alternative frameworks	No knowledge of students' alternative frameworks	No knowledge of students' alternative frameworks
Used many scientific terms consistently	Used some scientific terms	Used some scientific terms
Explained some of the scientific terms	Explained some of the scientific terms	Explained some of the scientific terms

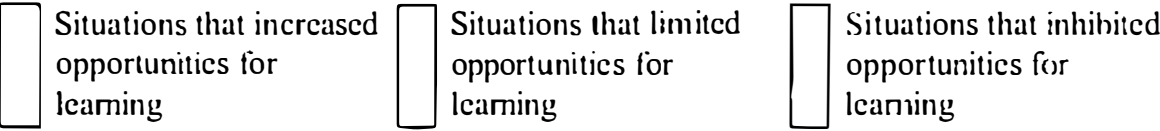


Figure 5.7. Whole-class teaching: Opportunities for learning

The Teachers' Management of and Strategies Used During Whole-class Discussions Related to Current Activities

Teachers need to be able to present information in a variety of ways and, where necessary, extend the teaching or relate it to other areas (Carlsen, 1991b; Sanders et al, 1993; Wilson et al, 1987). Both Mr Avery and Mr Carter demonstrated their understanding of electric circuits by allowing the discussions to extend into areas other than those intended and, when students offered unusual ideas or constructed unusual circuits, were able to respond. However, Mr Carter was unable to recognise some unscientific ideas held by the students.

Assertion 5/20

Teachers with a good knowledge of the topic are able to use a wider variety of contexts for developing ideas.

Assertion 5/21

Teachers with a good knowledge of the topic allow the ideas and activities to be extended by students and are able to comment on and evaluate these.

All of the teachers used some demonstration-type activities but the variety and number of them differed and they varied between the review sessions and those treating current activities. Ogborn et al. (1996) suggested that the use of strategies such as demonstrations help to clarify explanations, but they also help maintain the students'

interest, more so if students are in a position where they can see easily. In Mr Avery's class the students were either moved to the front of the class for demonstrations or Mr Avery took the demonstration to each group in turn. Ms Brown always left her students at their desks where they would have been unable to see some of the demonstrations. Mr Carter sometimes moved the students but also sometimes left them at their desks from where they would have been unable to see clearly. When the students are unable to see the demonstrations they cannot actively participate in the lesson and their learning is likely to be inhibited (Pintrich et al., 1993; Strike & Posner, 1992; Villani, 1992).

Assertion 5/22

When students are moved to the front of the class during discussions or demonstrations, student attention and participation is improved.

The sharing of students' ideas is important (Cosgrove & Osborne, 1985a, 1985b; Driver & Oldham, 1986) and all teachers at some stage allowed the students to draw diagrams of their circuits on the blackboard. When several diagrams needed to be drawn, Mr Avery asked the students to draw whilst the other students were still engaged in an activity and then used the diagrams as a basis for discussion. On one occasion when only two diagrams were being drawn, he asked students to draw whilst others were watching and gave a running commentary on their drawings, helping to maintain interest. Ms Brown frequently had students drawing on the blackboard whilst the rest of the class were expected to watch and did not comment on the drawings until they were complete, often only making basic comments. There was always a considerable amount of off-task behaviour during these sessions. Mr Carter only had the students drawing on the blackboard occasionally and the sessions moved faster than Ms Brown's although the students still got restless. The opportunities were there for the ideas to be developed but the lack of attention from the students in some situations indicated limited interest and participation.

Assertion 5/23

Where student blackboard drawing is completed when the other students are still working, the students are more likely to pay attention when the drawings are brought to their notice.

Assertion 5/24

Where blackboard drawing is accompanied by teacher explanations, the students' attention is better and they have more opportunity to recognise the ideas of other class members.

The quality of explanations varied. Mr Avery, with his good understanding of electric circuits usually gave clear explanations at relevant points in the discussion. He was also able to recognise errors and use demonstrations and explanations to address these. Mr Carter usually gave good explanations but he did offer and accept some scientifically incorrect ideas. Ms Brown's explanations were often less clear and it was apparent that some of her understanding was limited, with students demonstrating uncertainty about what she was trying to explain. She also gave the students no opportunity to question. Ogborn et al. (1996) felt that the teacher's pedagogic style has an important influence on the presentation of explanations but the teacher must consider the class needs and should incorporate questions into the explanations. Ms Brown tended to restrict the discussion and did not allow any deviation from the topic. This may have been a symptom of her more limited knowledge (Carlsen, 1992; Sanders et al., 1993). Mr Avery and Mr Carter had a very different pedagogic style to Ms Brown and this influenced their presentation of information. These ideas support Assertion 5/20 (Teachers with a good knowledge of the topic present information in different ways) and introduce three new Assertions.

Assertion 5/25

Where a teacher's understanding of a concept is limited s/he may not recognise students' explanations based on alternative frameworks and may accept or reinforce these.

Assertion 5/26

The teacher's knowledge of the topic affects the quality of his/her explanations.

Assertion 5/27

Clear and accurate explanations from the teacher give students the opportunity to develop scientifically acceptable understandings.

The teachers' use of predictions varied, with all teachers using them although Ms Brown's responses to the students' answers tended to cue students to the correct answer. Neither she nor Mr Carter always followed-up and discussed the correct predictions although Mr Carter was more likely to than Ms Brown. (Ogborn et al. (1996) considered that it was important to obtain a variety of answers so that students had an opportunity to compare their ideas with those of other students, but that the correct answer should always be given. This reinforces Assertion 5/9 (Responses from many students allows teacher to be aware of different understandings) but also introduces two more.

Assertion 5/28

The tone of a teacher's voice may cue the students to the correct response.

Assertion 5/29

The correct answer needs to be identified when a variety of responses are accepted for an open question.

In the classes where a variety of answers were accepted by the teacher, the students had the opportunity to recognise that there were other possible understandings and were able to consider and evaluate these.

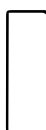
Assertion 5/30


The generation of a variety of ideas leads students to recognise and question other's ideas.

Summary

When the teacher behaviours that relate specifically to the treatment of current activities are summarised, it is apparent that most of Mr Avery's strategies and behaviours engaged the students and offered opportunities for learning. Mr Carter, however, engaged in some behaviours that might limit opportunities for learning and Ms Brown's management of discussion had few positive aspects with many of her behaviours likely to limit the students' attention and their learning opportunities (Figure 5.8).

Mr Avery	Ms Brown	Mr Carter
Wide knowledge allowed discussion to extend into other areas	Discussions limited	Reasonably broad knowledge allowed discussion to extend into other areas but accepted some incorrect answers
Wide knowledge allowed acceptance and use of student ideas	Limited knowledge required outside assistance when students offered unusual ideas	Willing to accept student ideas but limited knowledge allowed some incorrect answers to be accepted
Students moved so they could see demonstrations or demonstrations brought to students	Students stayed at desks for demonstrations	Students sometimes moved but sometimes stayed at desks for demonstrations
Students drew on blackboard whilst others were working	Students drew on blackboard whilst others were watching	Students only occasionally drew on blackboard whilst others were working
Blackboard drawings used with detailed explanations	Blackboard drawings used with limited explanations	Used good explanations with some blackboard drawings
Students involved verbally and physically in evaluating blackboard drawings	Students verbal involvement in demonstrations limited with no physical involvement	Students involved verbally and physically in evaluating blackboard drawings
Clear explanations	Explanations sometimes not given or unclear, but sometimes good	Not always able to offer explanations but those given were clear
Effective use of predictions	Limited use of predictions	Some good use of predictions
Teacher's responses neutral when several answers accepted	Teacher's response when several answers accepted cued students to correct answer	Teacher's responses when several answer accepted were not neutral but did not cue correct response
Where several answers accepted, correct answer eventually explained or demonstrated	Where several answers accepted, correct answer often not explained	Where several answers accepted, correct answer usually explained

 Situations that increased opportunities for learning

 Situations that limited opportunities for learning


 Situations that inhibited opportunities for learning

Figure 5.8. Whole-class teaching: Opportunities for learning specific to discussion of current activities

The Teachers' Management of and Strategies Used During Whole-class Discussions Related to Reviewing Work

Reviews are usually used in classrooms to check the students' recall of what has happened in previous lessons and to reinforce their understanding by reviewing material already covered (Gage & Berliner, 1992; Swift et al. 1988). However, they are also a useful tool for ensuring that students who have been absent have an opportunity to find out what has been happening.

Assertion 5/31

Regular reviews give students who have been absent for one or more lessons an opportunity to find out what has been covered.

The use of reviews differed between teachers. Mr Avery gave frequent, comprehensive reviews with many of the concepts covered several times. Ms Brown's reviews were very limited and Mr Carter, although his reviews were frequent, allowed the students' responses to direct the discussion, resulting in some topics not being covered. Mr Avery used not only the beginning and end of the lessons to conduct reviews, but often conducted them incidentally during the lessons when it was apparent that a concept was not understood. Mr Carter also conducted his reviews at a variety of times but his main sessions were at the beginning of the lessons. Ms Brown only conducted short reviews at the beginning of Lessons 2 and 3 and any within the lessons were generally very brief. Berliner and Rosenshine (1977) considered that reviews provide opportunities for links to be made between lessons, something that was done effectively in Mr Avery's and Mr Carter's class but which did not occur in Ms Brown's class. Tasker (1981) pointed out that students often do not recognise links between lessons unless they are overtly demonstrated. Where reviews are not used effectively the teachers have less opportunity to gauge the level of understanding in the class and the students have less opportunity to develop more scientific ideas.

Assertion 5/32

Students have more opportunities to construct understandings when time is allowed for regular, effective reviews of work to be conducted.

Assertion 5/33

Reviews directed by the teacher are likely to be more comprehensive than those where student responses guide the discussion.

Assertion 5/34

Where links are not clearly made between parts of a lesson and/or individual lessons, students may have more difficulty constructing understandings.

Ms Brown used no teaching aids during the review segments of the lessons but both Mr Avery and Mr Carter used a variety of strategies with Mr Avery using a greater range than Mr Carter. This supports Assertion 5/8 (Students are more attentive during animated discussions using many strategies) and Assertion 5/13 (Using a variety of teaching aids with clear explanations assists in developing understandings). When demonstrations were used during the review times, the students in Mr Avery's class were usually moved so that they could see the demonstration, whereas those in Mr Carter's class were not always moved resulting in more limited attention being paid and supporting Assertion 5/22 (Student attention is improved if they are moved to the front of the class for demonstrations). Both Mr Avery and Mr Carter used a range of question types, although there were fewer open questions than were used in the main activity-based discussions, and accepted a variety of answers before explaining the correct one. Ms Brown only used closed questions and accepted the first correct answer. The discussion related to questioning supports Assertions 5/11 and 5/12 (A variety of question elicits a wider range of response and open questions may be used in many situations).

The focus questions were provided in the lesson outlines as a guide to discussion. Mr Avery, on one occasion, gave the students copies of the questions and asked the groups to respond to the questions. This was followed by a whole-class discussion which covered many of the questions but not all of them. He sometimes made overt use of the focus questions after this but the concepts they covered were usually addressed in the whole-class discussions. Ms Brown's reviews rarely related to the focus questions, although some topics were covered. For three of the lessons Mr Carter gave the students a copy of the focus questions to discuss in their groups. However, he did not include a whole-class discussion on the questions, so there was no check to ensure that the explanations that the students had developed were correct. This is consistent with Smith and Neale's (1989) finding that teachers may omit significant parts of the supplied curriculum without realising the effects, and supports Assertion 5/14 (Information provided in the curriculum may not be effectively used) and 5/15 (Teachers may not recognise the effects of omitting a part of the curriculum).

Summary

A summary of the types of reviews and the teachers' behaviours during these lesson segments shows the differing learning opportunities that each teacher offered. Mr Avery's frequent comprehensive reviews that covered most concepts and encouraged student participation, allowed the students far more opportunity to develop understandings than Ms Brown's very limited reviews. Mr Carter's review sessions were more productive than Ms Brown's, but he did limit the students' learning by not covering all the concepts and by not discussing the focus questions (Figure 5.9).

Mr Avery	Ms Brown	Mr Carter
Frequent comprehensive reviews at a variety of points in lessons	Very limited reviews	Frequent but limited reviews
Reviews teacher directed and covered most concepts	Reviews teacher directed but limited	Reviews student directed and concepts missed
Students often moved for review demonstrations	Not applicable	Students not moved for review demonstrations
Used a variety of teaching aids	Used no demonstrations or aids	Used some demonstrations
Used a variety of question types	Used closed questions	Used a variety of question types
Often obtained a range of answers before selecting correct one	Accepted first correct answer	Sometimes accepted a variety of answers
Discussed focus questions with whole class	Did not discuss focus questions	Did not discuss focus questions with the whole class

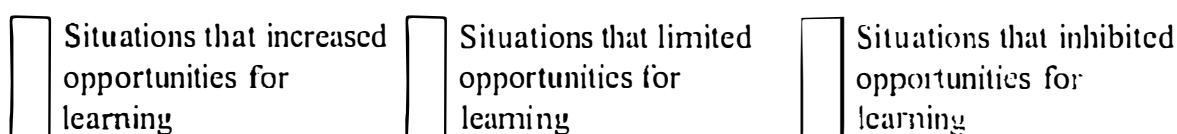


Figure 5.9. Whole-class teaching: Opportunities for learning in reviews

The Students' Participation and Behaviours During Whole-class Discussions

In both Mr Avery's and Mr Carter's classes the students were involved in the construction of explanations, both through the teachers' questioning and by the students' input to the discussion. This helped maintain a high level of interest and attentiveness during the discussion time.

Assertion 5/35

The students' involvement in the construction of explanations during discussions helps to maintain interest and allows them more opportunities to develop understandings.

To benefit from the learning being offered, students need to participate and be actively involved in the discussion (Driver et al., 1994; Pintrich et al., 1993; Wells,

1989). The students from Mr Avery's class demonstrated active involvement by often making suggestions or offering ideas when Mr Avery was demonstrating and explaining. They were also likely to ask questions that were not necessarily directly related to the topic. Mr Carter's students also did this occasionally although not to the extent of Mr Avery's. Ms Brown's students rarely offered any suggestions or ideas.

Assertion 5/36

When students are interested and involved in the discussion they are more likely to ask questions and offer suggestions.

Student responses give them an opportunity to not only put their ideas into words, but to also check them and compare them with those offered by others (Spada, 1994; Vosniadou, 1994). The students in both Mr Avery and Mr Carter's classes were willing to argue points with their teachers when they did not agree with their statements. When these students responded to questions they often offered extra information, sometimes extending and/or justifying their answers. This gave the teacher and the other students an opportunity to recognise their understandings. The students in Ms Brown's class offered minimal answers and Ms Brown often had to question them to gain a full answer, which resulted in fragmented answers that were difficult to understand. Although both Mr Avery and Mr Carter usually summarised student answers to produce a complete answer, Ms Brown usually did not.

Assertion 5/37

The students' ability to extend or justify their answers allows more complete answers to be generated and gives teachers more opportunity to recognise understandings.

Assertion 5/38

Where explanations or student answers are fragmented it is more difficult for other students to construct understandings.

Assertion 5/39

Where teachers need to use many questions to help students respond, the fragmented answers need to be summarised to clarify the explanation.

In Mr Avery's class, the students were involved with many of the activities during the whole-class discussions and reviews. The students were included in the practical demonstrations in a variety of ways, by helping with the circuits or by checking them. Mr Carter also involved the students in his demonstrations but, during the review time, the students were less likely to be physically involved. However, he did tend to draw many students into the discussion by his use of role-playing and analogies. Ms Brown's students, apart from the suggested role-play and the blackboard drawing, were never involved in activities.

Assertion 5/40

When students are involved in meaningful demonstrations they and the rest of the class are more attentive.

Mr Avery also involved the students more in evaluating and correcting the blackboard diagrams. After engaging in discussion about the drawings he would ask a students to come up to the blackboard and correct the diagrams. Although he did not ask the students to change diagrams, Mr Carter did involve them in discussion designed to help them to recognise errors in the diagrams. Both of these strategies allowed the students to become more engaged in the activities and gave them opportunities to improve their own understandings (Driver et al., 1994, Vosniadou, 1994). The students in Ms Brown's class were only involved in a very minimal amount of discussion about blackboard diagrams with Ms Brown giving some information but rarely asking for input from the students.

Assertion 5/41

When students are involved in evaluating and correcting blackboard diagrams, there are more opportunities for the development of scientifically acceptable understandings.

Lemke (1990) argued that students need practice in using science language and should be able to reword their understandings to fit differing situations, and Wells (1981) suggested that opportunity for practice could be provided by students explaining their ideas to others. Generally, regardless how much a term was used by the teacher, students did not include new terms, often concept labels, in their discourse. Lemke (1990) considered that students needed practice in using the scientific language, but

even in the classrooms where there was a considerable input from the students, the new terms were used infrequently. They did use the common terms, which were usually object names, although their understanding was not necessarily accurate.

Assertion 5/42

Students are unlikely to use many new scientific terms in their discussions.

Summary

When the participation of the students from the three classes in discussions is examined, the students from Mr Avery and Mr Carter’s classes demonstrated a much greater involvement in the lessons than those from Ms Brown’s class. They were attentive and enthusiastic, and played a greater role in the development of the discussion. Ms Brown’s students were unenthusiastic participants who offered minimal information and had little input to the content of the discussion (Figure 5.10)

Mr Avery’s students	Ms Brown’s students	Mr Carter’s students
Involved in the construction of understandings	Rarely involved in constructing understandings	Involved in the construction of understandings
Generally attentive during whole-class sessions	Inattentive during whole-class discussions and often talking or using equipment	Generally attentive during whole-class discussions with a small group off-task
Willing to argue with the teacher	No argument	Willing to argue with the teacher
Offered ideas and suggestions	No ideas or suggestions offered	Offered some ideas and suggestions
Expected to think and justify answers	Gave only limited factual answers	Expected to think and justify answers
Involved verbally and physically in demonstrations and the evaluation of blackboard drawings	Verbal involvement in demonstrations limited with no physical involvement	Involved verbally and physically in demonstrations and verbally in the evaluation of blackboard drawings
Showed interest and enthusiasm and were keen to participate	Showed little interest or enthusiasm	Showed some interest and enthusiasm. Most students keen to participate
Asked questions (other than procedural)	Only asked procedural questions	Asked questions (other than procedural)
Offered extra information	Offered very limited information	Offered some extra information
Did not use scientific language used by teacher	Did not use scientific language used by teacher	Did not use scientific language used by teacher

Situations that increased opportunities for learning

Situations that limited opportunities for learning

Situations that inhibited opportunities for learning

Figure 5.10. Student involvement in whole-class discussion: Opportunities for learning

It is apparent that the teachers varied in their use and management of the whole-class discussion time. Mr Avery used the time effectively, dividing it between reviewing work and treating current activities and his management of the discussions allowed his students opportunities to participate and learn. Ms Brown spent little time reviewing the work that had been done and making links between the activities and lessons, and her management of the discussions did not allow effective student participation and limited the opportunity for learning. Mr Carter's reviews were more comprehensive than Ms Brown's but did not address all the work that had been covered. His management of the discussions allowed student participation and opportunity for learning, but his more limited knowledge allowed unscientific statements to go unchallenged and did not ensure that the learning that was occurring was scientific.

The next chapter examines the teacher's interactions with students during small group activity work.

CHAPTER 6

Teacher Interactions with Small Groups and Small Group Work

Overview

This Chapter is an overview of the teaching and interactions that the teachers engaged in when the students were involved in group work. Following the details of the three teachers' teaching, the discussion relates some occurrences to assertions that have already been developed and also leads to the development of new assertions.

Mr Avery

General

Apart from a limited number of interruptions from visitors, Mr Avery spent the majority of the group activity time working with the students or looking for equipment. The instructions were read to students or given to them before they moved into group work, and Mr Avery expected the students to then follow the instructions on their worksheets and progress at their own rate through the activities, gaining his attention if they were having difficulties. He attempted to visit most groups during activity sessions and consequently his visits were fairly short, although, where necessary, he stayed with some groups for longer periods. Two students in the class had reading difficulties and Mr Avery, in his visits, helped them read and understand the instructions. He had a friendly manner when interacting with the groups using firm control methods where necessary. Although Mr Avery did not suggest extension activities to individual groups, he did suggest them to the whole class. He also ensured that all groups had opportunities to examine items that had been discussed in the whole-class discussions.

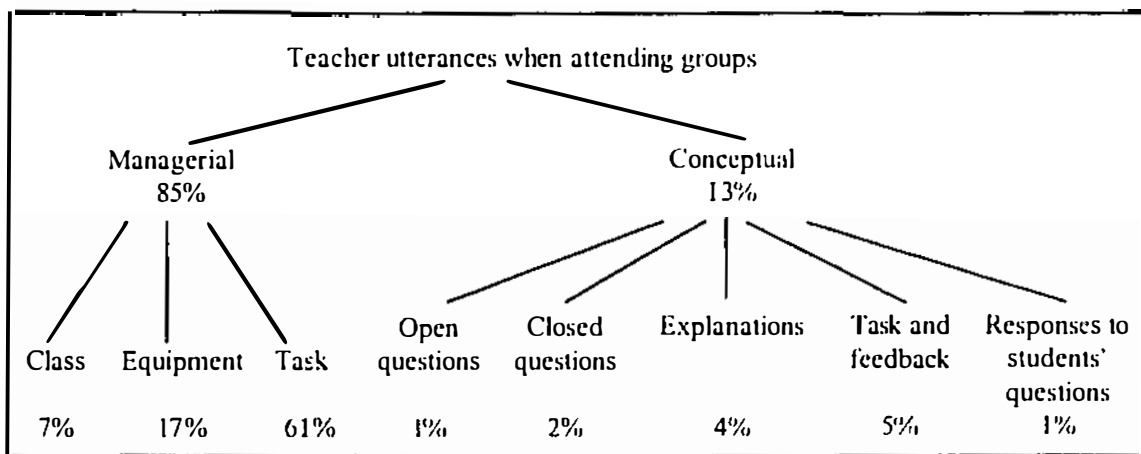
Because the students were able to proceed at their own pace, there was only limited off-task behaviour and students tended to be very involved in the activities. Some groups occasionally did not follow the instructions but they were generally using the equipment sensibly.

Mr Avery asked the groups to complete most of the activities in the lesson outlines, although he adapted some of the work to his teaching style.

Interactions between Mr Avery and Groups

An analysis of the interactions indicates that the utterances from students were similar in number to those from the teacher, with the teacher contributing 49% of the

utterances and the students 51% although the teacher's utterances were: generally longer than those of the students.



Note: A further 2% of comments were general comments or unintelligible

Figure 6.1. Teacher utterances by category when attending groups

The majority of interactions (85%) tended to be managerial (Figure 6.1) with 17% of the statements from Mr Avery relating to difficulties with equipment, mainly arising from missing elastic bands and blown globes. Seven percent of comments related to management of the students within the groups, sometimes managing behaviour problems and sometimes ensuring all students had an opportunity to participate:

Mr Avery	Yes well, you've got to work together.
Student	They don't want to.
Student	They don't want to.
Student	Yes we do.
Mr Avery	Alright. Can you boys pack up if you can't work cooperatively. (Lesson 2)
Mr Avery	Have you le, boys are you letting the girls have a look at it?
Student	Yeah.
Student	No.
Mr Avery	Come on, let's share it thank you. (Lesson 1)

Sixty-one percent of Mr Avery's comments related to checking the students' work, either activity or written, most occurring when he was helping to build or correct the circuits constructed by the students. He often demonstrated or explained the correct procedure rather than encouraging the students to investigate for themselves:

Mr Avery	And now where's your little piece here. Just connect these two. Did you see that girls? (Lesson 2)
Mr Avery	Right, Let's have a test. It's not working. All these terminals. Screw it up. It isn't screwed in. (Lesson 3)

The type of questioning during this time was usually not designed to produce or encourage conceptual discussion but to ensure students were on-task. Most questions were closed and usually related to the construction of circuits:

Mr Avery *Who has checked the globes. Have you got three different globes?*
(Lesson 3)

Mr Avery *Okay how are you going to connect them up?* (Lesson 3)

Only 3% of the utterances were questions that would have assisted in developing understandings with 2% of these being closed questions (Table 6.1). Over half the open questions were directed at the Focus Group in Lesson 2, with no other group having a similar amount of conceptual discussion. In the first long segment of discussion with the Focus Group Mr Avery used the circuits that the Focus Group had made to demonstrate that the circuits made in Lessons 1 and 2 were the same and had the same effect. The second less successful discussion took place after the students in the Focus Group had added drawing pins to their circuits:

Mr Avery (reading from a student's notes) *The current's going through the pins. Aah. What's that tell us about the pins?*
Student *It tells us that it makes the circuit complete.*
Bob *That the electricity will run through.*
Mr Avery *Good, it makes it complete.*
Mr Avery *What was were you saying, Bob?*
Bob *Electricity will run in metal.*
Mr Avery *Good, it goes through metal. So metal remember those, oh, two new words that we're going to learn today. A conductor. Do you know what a conductor is?* (Lesson 2)

The discussion continued for some time with Mr Avery unsuccessfully attempting to elicit the scientific meaning of conductor. Mr Avery did talk to one or two other groups in an endeavour to develop better understandings, but this was infrequent. However, the students did offer detailed responses when he did and this allowed him to develop a better understanding of the students' ideas:

Mr Avery *Now how's the holder follow the same idea?*
Student *It's got metal, it's got metal there which joins up to the bottom and there, so the negative might come through that end and go that way and then * it might come back through this way back on to the battery.*
Mr Avery *Mmm. Alright. So if you have a close if you have a look at it, see how it's got at the bottom, See how it's got at the bottom a little pin or a little point.*
Student *That's where the bottom of the globe goes.*
Mr Avery *That's where the bottom, that's right. That's where the bottom goes. Now see in there, how it's got that little pin in there, that little*

Student *Oh, yeah.*
Mr Avery *So it touches the bottom, the lead part touches that bottom part and then you've got something touching the outside. (Lesson 2)*

Most discussions that occurred between Mr Avery and the groups reached a conclusion and, if several answers had been offered, Mr Avery usually explained the correct answer, but not always. Understandings that had been developed during discussion with groups were usually disseminated to the class.

When talking to groups, Mr Avery rarely reviewed previous work which may have assisted individual students to make links between activities or lessons. Four percent of his comments were explanations. These usually described what was happening in the circuits, sometimes using circuits to enhance the explanation:

Mr Avery *Because the batteries obviously they had, it's a different levels of energy. (Lesson 2)*

Mr Avery *Now we said that the globe, we said that was the important part and that was the important part, didn't we and the other thing was this end and that end. What's going to happen? Will that work for me or not? See that? (Lesson 1)*

There were five percent of the comments classified as conceptual which related to the task and to feedback (Figure 6.1). The feedback referred to comments that indicated the students had made conceptually correct judgements or comments, with the task comments generally directing the student activities so that the correct understandings were being used:

Mr Avery *Now you've got to connect, you've just got to get that circuit. Remember the the idea of a circuit? That's the way. Join the other one. (Lesson 2)*

Student Participation

Seventy-three percent of student comments related to task management including 15% relating to equipment management (Figure 6.2).

Student *Mr Avery, both of these packs are missing stuff. (Lesson 4)*

Student *Is it supposed to be done as a group? (Lesson 3/4a)*

Only 12% helped to develop conceptual understanding. Four percent of these involved informational statements directed to Mr Avery with students both offering general information and enthusiastically sharing their successes:

Student *We've found two the first two worked very well. (Lesson 1)*

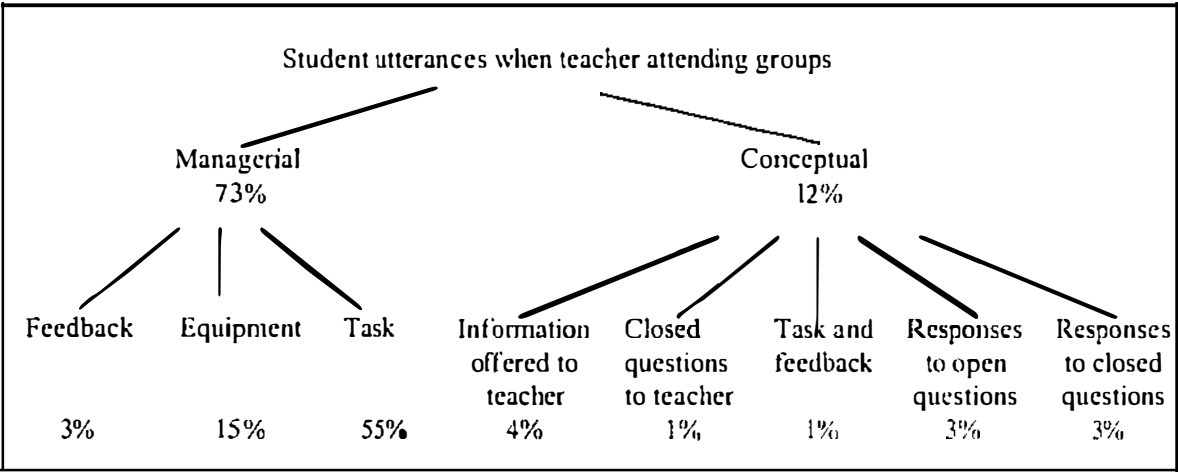
Bob *Hey, look it's brighter, Mr Avery.*

Mr Avery *Ooh, which one's brighter? Oh that's using two, yes. We're only using one battery today. (Lesson 2)*

All the student initiated questions were closed and most related to the task rather than to developing understandings although sometimes they were used to check the student's ideas:

Pat (Referring to the position of the wires to the globe on Mr Avery's blackboard diagram) *How is it supposed to work on the side? You've got the wires on the side.*

Mr Avery *On the sides. It doesn't work on the sides. Oh right. That's a good point. We're not actually connecting to the sides. We're trying to form a circuit around that way. (Lesson 3/4)*



Note: A further 15 % of comments were general comments or unintelligible

Figure 6.2. Student utterances by category when teacher attending groups

Occasionally a student would demonstrate some extended thinking in his or her questions:

Student *Mr Ave, if ifum, you had a blown globe and you um broke the glass off after it was blown and stuck it together would it work again? (Lesson 3)*

Six percent of the utterances were responses to Mr Avery's questions with three percent of these being answers to closed questions (Table 6.1). The students often answered closed questions with the expected answer and then added extra information allowing Mr Avery more opportunity to assess their understanding:

Mr Avery *Good. The next part then is take it and put it two centimetres apart. That's two centimetres. Would you expect it to light up now?*

Student *No.*

Mr Avery *No. See we've got that.*

Student *Because it's apart and you can't touch it. (Lesson 2)*

Although only one percent of Mr Avery’s utterances were open questions, three percent of the students’ utterances were responses to open questions because several students were given the opportunity to respond:

Mr Avery *Okay then, what have you decided on? What 's the consensus?*
Sue *Well, first*
Jon *All the less volt.*
Pat *The battery's only 1.5*
Mr Avery *Yeah, the smaller the*
Pat *Only if it 's 1.5 gets more because it 's smaller*
Pat *This one gets less because it 's bigger.*
Jon *It draws more energy.*
Bob *Yeah, because it needs more energy. Because the battery's only small and it needs more volts.*
Pat *It needs more energy.*
Ann *Volts to go brighter.*
Sue *It might it might light up.* (Lesson 3)

Included in the 15% of comments that were general or unintelligible due to recording difficulties, were a small number of topic-related comments generally asking about the purchase of equipment (Figure 6.2).

Table 6.1
Types of Interactions Between Mr Avery and Students in the Small Group Situation

Type of utterance	Percentage of utterances from:	
	Mr Avery	Students
Managing class or group	7	3
Managing equipment	17	15
Managing task	61	55
Explanations	4	
Open questions	1	
Responses to open questions		3
Closed questions	2	1
Responses to closed questions	1	3
Information from students (conceptual)		4
Task management (conceptual)	5	1
Unintelligible	1	11
Other	1	4

Most of the utterances from both Mr Avery and the students were related to management, with most of those referring to task management. There were a few interactions relating to task management that had a conceptual component, with more of

these coming from Mr Avery than from the students. A small percentage of Mr Avery's utterances were questions with a further 4% explanations. Four percent of the students' utterances provided conceptual information (Table 6.1).

Use of Scientific Vocabulary

The words most commonly used by both the teacher and the students were battery, globe and circuit with these generally used in connection with the construction of circuits. Positive and negative were also used consistently, although most usage was in the last lesson when the student were using series circuits to build a nerve tester. All the other scientific terms were only used infrequently in the teacher/group discussions.

Ms Brown

General

There were few interruptions during the group work time and Ms Brown spent most of this time working with the students or, occasionally, looking for equipment. Prior to the activity time she would ask a student to read the instructions for the activity and then often repeat the instructions. She would then circulate fairly quickly through the groups checking that they had the correct equipment and repeating instructions:

Ms Brown You need three wires this time, one battery, the globe holder. You may have enough to for the other group for the other side to make theirs as well. (Lesson 2)

Ms Brown You can have a battery holder. You need two wires, a battery holder. Yes, you need the alligator clips. (Lesson 3)

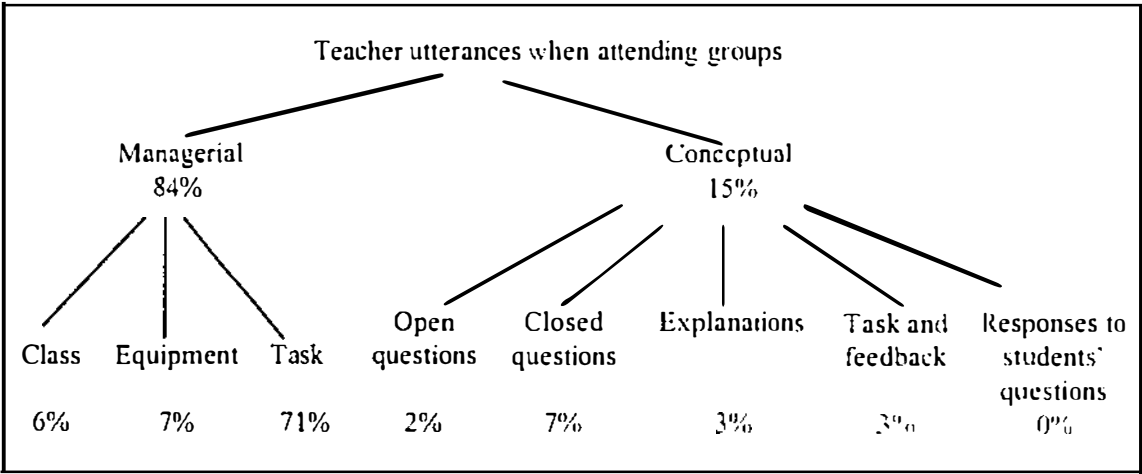
The students were expected to progress through the activities as a class and some students had some considerable time to wait before moving on to a new activity. Her patterns of group visits varied with the activity. When the students were constructing circuits she tended to visit a limited number of groups, but when they were completing written work she often visited most of the groups to check on their work, sometimes picking-up on a common error and informing the whole class of the problem. One group included a special needs student, who was described as working at about a Year 3 level, and, during the first lesson, Ms Brown spent extra time with him endeavouring to explain how a circuit should be connected so a globe would light. As with her whole-class discussions, her interactions during the group visits were formal and discussions with the groups were strongly teacher centred. Ms Brown, did not suggest any extension activities either to the groups or to the whole class and did not ensure that information given to groups was also given to the class.

All Ms Brown's groups were mixed gender groups and she felt by Lesson 3 that the students were not co-operating well and, as described in Chapter 4, set up a system to ensure everyone would have a turn at constructing circuits, although her system was not maintained by all groups. There were, however, few instances of students complaining that they were not having a turn and Ms Brown was not required to solve group arguments on this topic.

Ms Brown organised the lessons so that groups completed all of the practical activities in the lesson outlines.

Interactions Between Ms Brown and Groups

An analysis of utterances indicates that both students and teacher contributed similarly, Ms Brown contributing 51% of the utterances and the students 49%. However, Ms Brown's utterances were generally longer than the students.



Note: A further 1% of comments were general comments or unintelligible

Figure 6.3. Teacher utterances by category when attending groups

The majority (84%) of Ms Brown's utterances were managerial (Figure 6.3). There were few problems with the equipment but, on two occasions, Ms Brown spent some time with groups that were having difficulties, and these account for most of the interactions related to equipment management. Six percent related to managing group behaviours, usually ensuring that the students were following the instructions but sometimes checking on other behaviours:

- Ms Brown* Have you got any others? No, don't use that. Just use the globe. You were told to use one battery, one globe and one piece of wire. (Lesson 1)
- Ms Brown* Yes, there's one. That means you're going to have to share. (Lesson 2)

Most of the management utterances were related to task management which included repeating or giving further instructions and checking students' work and all questions were closed:

Ms Brown *Screw the globe into the globe holder. Screw it in. Is that the smallest globe you have?* (Lesson 2)

Ms Brown *Luke, is it your turn now? Whose turn?* (Lesson 3)

Ms Brown rarely helped students with the construction of circuits and her helping comments were often very general:

Ms Brown *It was working all right? All right. You're going to have to fiddle with that to get that circuit working properly before you put your other one in.*
(Lesson 4)

On one occasion when a group of students had constructed a circuit which did not work, Ms Brown needed outside help to ascertain what the problem was.

There were only limited occasions when Ms Brown engaged in discussion that might develop conceptual understandings and these included few open questions (Table 6.2). Most open questions occurred during the first lesson when Ms Brown was working with two groups to try to develop the correct understanding of the direction of current flow in a circuit, with a further two open questions in Lesson 2 when discussing why galvanised wire would not conduct electric current. In the first lesson only one group engaged in a discussion that developed correct understandings with only one student in the group actually voicing the correct response. Ms Brown involved another group in a similar discussion but they did not reach a correct scientific understanding, with Ms Brown finally appearing to agree with their ideas:

Ms Brown *So you've got electricity coming from there and also through there. Is that what you think?* (A bi-polar view)

Student *Yup.*

Ms Brown *Right, okay.* (Lesson 1)

Although information discussed with the groups that related to written tasks was disseminated to the class, some conceptual understandings were not. The amount of whole-class discussion was limited and it is possible that students may have retained incorrect understandings generated during the group discussions.

Often discussions did not appear to reach closure and the questions were left unanswered. Sometimes discussions which could have led to understandings being developed seemed to be terminated without the necessary interactions:

Ms Brown *So which way did you do it? You had that underneath.*
Student *We*
Ms Brown *Right. And what did you do with the globe?*
Student *Put it underneath then we pushed this on to *.*
Ms Brown *Put there. What happens if it goes there?*
Student *Oh.*
Student *See, my way was better*
Student *I never said it wasn't.*
Ms Brown *So what do you notice*
Student *That Mary's worked didn't work and mine did. (Lesson 1)*

Most questions were closed questions and often directed to students to look at the circuits they had constructed:

Ms Brown *So which one worked? This one where it's at the side there. (Lesson 1)*
Ms Brown *Right, you've got your two batteries. When you put your two batteries together what did you notice was written on them? Were they positive or negative ends that you had together? (Lesson 3)*

Ms Brown rarely reviewed previously taught understandings when talking to groups and, because of the limited reviews that occurred during the whole-class discussion time, her students had few opportunities to make links between lessons and activities. Ms Brown gave only limited explanations that would develop understandings. In Lesson 1, all her explanations to groups were related to the positive and negative terminals of a battery although the word 'terminal' was not used. There were few other explanations, although in Lesson 3, Ms Brown did explain why some of the 4.8 volt globes were flashing to two groups with the explanation not offered to the whole class.

Three percent of Ms Brown's task related comments may have helped develop conceptual understandings, for example, when she was encouraging the students to investigate the galvanised wire's conductivity further:

Ms Brown *But perhaps try your wire, just putting your cut end to cut end.*
 Connecting that up to your cut end. See what happens then. (Lesson 2)

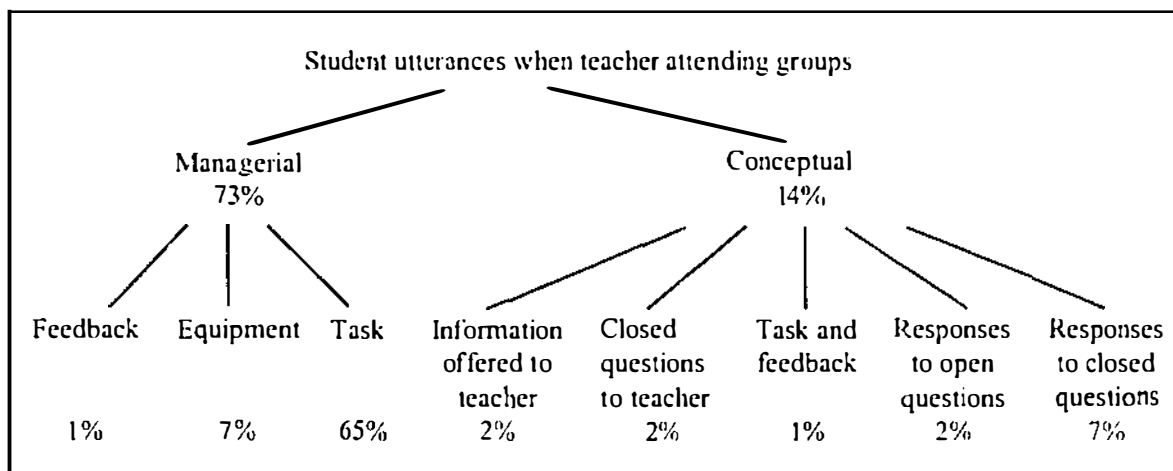
Ms Brown, particularly when the students were working on the Summary Sheets, often read what they had written and commented on it or questioned it. However, the comments were often product oriented with the intention of improving the written work.

Student Participation

Student involvement was restricted during the group activity time because they needed to wait for instructions before moving on to a new activity. Many groups became off-task during this time as they had completed the work and, although some

groups did continue working with the circuits, most groups waited for the next set of instructions.

The categories and numbers of student utterances were similar to those of Ms Brown (Figure 6.4). As with Ms Brown, the majority of the student utterances related to task management (65%) with many of them being group conversation incidental to the presence of Ms Brown and in which Ms Brown did not engage. They often used the teacher's visit to check that what they were doing was correct or that their circuits were right.



Note: A further 13 % of comments were general comments or unintelligible

Figure 6.4. Student utterances by category when teacher attending groups

When information was offered by the students it was usually related to which circuits worked or what happened with no real understanding demonstrated:

Student *They're not as bright.*
Ms Brown *Let's have a look. Okay. This is interesting. (Lesson 4)*

No further discussion was entered in to and it was rare for students to voluntarily offer information about their understandings or to share their successes and ideas.

Discussions included responses to closed question, which may have developed some understanding (Table 6.2). These however, were often terminated with little understanding demonstrated:

Student *The second one we tried it there without this and it doesn't glow only one works, only one really works*
Ms Brown *You're using 1.2 globe volt globes?*
Student *Yes*
Student *No, 1.2 that's 1.2.*
Ms Brown *You got a flash of light there. Okay. Right. You you put down your predictions?*
Student *Yep. (Lesson 3)*

Most of the responses to open questions occurred in Lesson 1 when discussing direction of current flow. The closed questions asked of Ms Brown usually required her to confirm the action that the students was about to take:

Student Shall I put the globe on there? (Lesson 1)

Student Three 4.5 volt ones and then nine two 9 volt batteries. Would it matter if I did that? (Lesson 3)

The students' responses to questions were usually short and offered little explanation, allowing Ms Brown little insight into their understandings.

Table 6.2

Types of Interactions Between Ms Brown and Students in the Group Situation

Type of utterance	Percentage of utterances from:	
	Ms Brown	Students
Managing class or group	6	1
Managing equipment	7	7
Managing task	71	65
Explanations	3	
Open questions	2	
Responses to open questions		2
Closed questions	7	2
Responses to closed questions		7
Information from students (conceptual)		2
Task management (conceptual)	3	1
Unintelligible	1	13
Other		

Most utterances from both Ms Brown and the students related to task management with some having a conceptual component. The next highest category was closed questions with 11% of Ms Brown's utterances being questions, and 12% of student utterances being responses (Table 6.2).

Use of Scientific Vocabulary

Ms Brown's use of battery, globe and circuit were very high in these discussions, with positive and negative also being used often. This usage was nearly all related to the building of circuits or to the initial instructions given when Ms Brown first circulated round the groups. The students' use of these words was also quite high although less so for 'circuit'. Switch was used often but only when Ms Brown was

questioning the students about where they planned on putting their switch. The remaining scientific terms were used infrequently by both Ms Brown and the students.

Mr Carter

General

There were few interruptions from visitors during the group work time and Mr Carter spent most of this time with the groups. Rather than work straight from the worksheets, Mr Carter tended to reorganise the activities and give the instructions prior to the activity. He did not expect the students to progress at their own rate, but the lessons were fast paced and students did not appear to get bored or off-task. Mr Carter tended to visit most groups early in the session to ensure they were all aware of the task and were not having difficulties, usually picking-up on specific problem areas:

Mr Carter *See if you can get your circuit to work.* (Lesson 2)

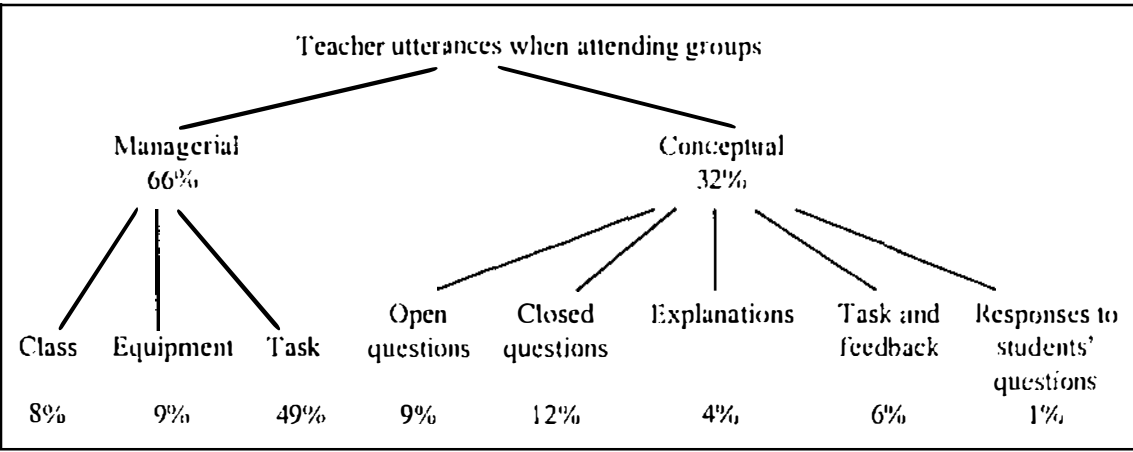
Mr Carter *You should have a globe holder. You should have a battery.* (Lesson 2)

These instructions took a very short time. Generally, after this, he visited a limited number of groups for much longer periods of time. His interactions with the groups during these visits were friendly and he tended to use the nicknames that he had for the students although, when necessary he used firm control methods. As with his whole-class discussions, he encouraged the students to think. He did offer extension activities to those groups that needed them, but not all groups had these opportunities. However, he did also occasionally suggest extensions to the whole class. Usually, information given to the groups was given to the whole class but this was not consistent.

The groups did not complete all of the activities in the lesson outlines, and some activities were condensed by Mr Carter resulting in students not having the opportunity to develop the correct understandings.

Interactions between Mr Carter and Groups

An analysis of interactions shows a very different pattern to the interactions of the other two teachers with 40% of the interactions being from Mr Carter and 60% from the students. He would often attend a group and listen to the group conversation before joining in the discussion. Mr Carter's visits to the groups were task-oriented but there was a higher level of conceptual discussion than in the other two classes.



Note: A further 2% of comments were general comments or unintelligible

Figure 6.5. Teacher utterances by category when attending groups

Over half of Mr Carter’s interactions (66%) were managerial (Figure 6.5). He had a limited number of problems with equipment, mostly related to missing globes, and most of the utterances in this category occurred in Lesson 3 when he checked to ensure all groups had the necessary equipment. Eight percent of the management interactions related to managing group behaviour. The tone of the interactions depended on the behaviours that were causing difficulties with Mr Carter sometimes rebuking in a fun way and other times taking stronger action:

Mr Carter *Oh, you did find it, Colin. Well done.*
Student *Yeah it was in my drawer.*
Mr Carter *Yeah. Blame Mr Carter. (Lesson 4)*

Student *Where's that big round one?*
Student *Carol threw it on the floor?*
Mr Carter *Go and sit out there. I'm not having your tantrums. Just go and sit down on the verandah, Carol, where I can see you. Over there. You're not throwing tantrums and that goes for anybody else in this room. (Lesson 2)*

There were few occasions when he needed to ensure all students had an opportunity to participate and he expected the students to solve some of their problems themselves but would offer suggestions to facilitate this:

Mr Carter *Bruce, you're part of the group. Don't complain to me. Tell them you're part of the group.*
Bruce *I'm part of the group.*
Student *I know.*
Mr Carter *Well spoken, Bruce. (Lesson 2)*

Forty-nine percent of the managerial interactions referred to task management, usually relating to the construction of circuits, and only infrequently referring to any written work. Although on occasion he assisted the groups in their constructions, he was

more likely to question the students to help them to find the answers, a situation which may have led to students developing a better understanding of circuits, and he encouraged the students to discover for themselves errors that they had made:

- Mr Carter* *How did, how. Did one globe go off when you, how did you get the second one to join in?*
- Student* *Added a battery.*
- Student* *Add another battery and another wire.*
- Student* *Which other wire?*
- Mr Carter* *Oh. Yeah. But didn't the first globe * go off when you were trying to add the second globe in?*
- Student* *Um, no.*
- Mr Carter* *Show me how you did it then. (Lesson 4)*

The students then demonstrated to Mr Carter how they constructed the circuit which led to the recognition that their circuit did not conform to the instructions. Generally the questions in the managerial categories were closed but they were sometimes designed to make the students think, rather than respond with little thought.

The amount of conceptual discussion was fairly high with Mr Carter often questioning the groups at some length and listening and responding to their answers to help develop understanding. After questioning, he often allowed the students to continue discussing amongst themselves before questioning further. Nine percent of his questions were open and a further 12% of the utterances were closed questions all of which would have assisted in building student understanding (Table 6.3). Although there are many examples of this style of conversation in groups, an example occurred in Lesson 4 when Mr Carter spent some time with the Focus Group discussing what might happen when a globe was unscrewed from the globe holder in a parallel circuit:

- Mr Carter* *What happens if we disconnect the other globe?*
- Colin* *Mmm. Nothing.*
- Geoff* *Should still keep going.*
- Student* *It'll keep on going because then the electricity'd pass * front of the battery and then to the other side.*
- Mr Carter* *You just disconnected this wire. Right. If you disconnect the first one, Blue What do you think's going to happen? Don't do it yet, Colin, I wanted to talk about it.*
- Linda* *Disconnect the globe?*
- Mr Carter* *Yeah, if you disconnect that one that Colin's trying to disconnect but he's not allowed to.*
- Linda* *Yeah. It should still go because the wire's gone through here and then it would go up into here.*
- Mr Carter* *Fair enough. Is that what you think, Stack?*
- Helen* *I think it might. It might not though because.*

Colin *It might still glow but really dull.*
 Linda *It might not. I don't think it's going through.*
 Geoff *I know, I know, I know.*

Mr Carter encouraged all the students to put forward their ideas and, although they did not immediately offer full explanations to support their responses, he encouraged them to produce arguments to convince the others that they were right. However, the girls in the group were still unconvinced after some considerable discussion:

Mr Carter *So, so, hold it. Why do you think it's going to go out, Helen?*
 Helen *Because if it goes through here, this thing here, and it goes up here it just won't*
 Mr Carter *So you think when we break the circuit from underneath the globe. Is that what you're trying to tell me?*
 Linda *Yeah.*
 Colin *But it's not underneath, it's the wire.*
 Linda *If we disconnected the globe then the wire might, the electricity might go through here and just pass through there. It might not.*
 Helen *Yeah.*

When the circuit was connected and the globe was working, Mr Carter asked the girls, who had been unsure, to explain why:

Linda *Because it does go through there.*
 Mr Carter *Okay.*
 Colin *Logical.*
 Mr Carter *Because, tell me about that black wire in relation to this yellow wire.*
 Linda *They're both joined.*
 Colin *They're touching.*
 Mr Carter *They're joined so therefore*
 Linda *It's connected up.*
 Mr Carter *Good girl. (Lesson 4)*

From Mr Carter's responses it is impossible to ascertain whether or not he was aware of what would happen when the globe was unscrewed and the resulting discussion from the students demonstrated the efficacy of Mr Carter's strategies. His discussion with groups varied and he sometimes brought the group's development of understanding to a reasonable conclusion, but sometimes the groups were either left with incorrect understandings or the questions had not been answered. As the topics were not always discussed as a class, the students had little opportunity to change their ideas.

Mr Carter also used relevant opportunities to review work that had previously been discussed, questioning the students to consolidate understanding and develop their answers more fully:

Mr Carter *What would happen if we put two batteries?*
Student *It'll pop.*
Mr Carter *It'll pop.*
Student ** globe really bright and it'll pop.*
Student *There's too much power for it.*
Student *There's too much energy for it.*
Student *There's just too much power there then it blows.*
Mr Carter *What's * what could we say rather than too much power though, too many*
Student *Energy. (Lesson 2)*

On some occasions Mr Carter was involved in discussions with groups where he accepted the explanations including some errors that occurred, and the group would be likely to assume that all their ideas were correct. As the correct understandings were often not covered in the whole-class discussions, they would be likely to retain their incorrect ideas:

Student *Mr Carter, the bottom of the globe has lead on it *.*
Mr Carter *Mm, amazing.*
Student *Why do they use lead?*
Mr Carter *You tell me.*
Student *Maybe because it's got metal and it's a good conductor because it's cheaper than's *.*
Mr Carter *What's conductor mean?*
Student *Anything that can transfer the power ** like the wire has a ability to travel er electricity to come *. (Lesson 1)*

As indicated in the extracts, Mr Carter also took any appropriate opportunity to check on or extend students' understanding of concepts and terms that they used. He was also willing to admit lack of knowledge. Because of the type of globes, the 4.8 volt globes started flashing when three 1.5 volt batteries were connected to them:

Student *Why does it flicker?*
Mr Carter *I don't know why it flickers.*
Student *Um, Carol said it was because they're getting too much energy, too much energy but if it gets too much energy it just blows.*
Mr Carter *I don't know why though, mate. I've no idea why.*
Student *With two it doesn't.*
Mr Carter *I'd agree that if you have too much energy you'd blow it. (Lesson 3)*

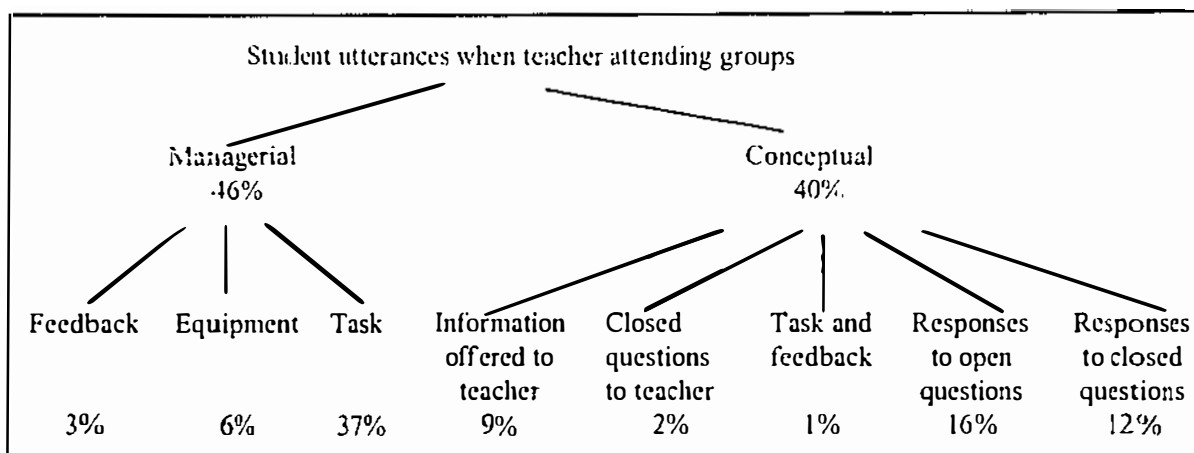
Mr Carter's explanations were brief and often repeated something that a student in the group had generated from the discussion rather than offering new explanations.

There were few task related comments and most of the six percent categorised as task and feedback were feedback from the teacher, often neutral but also emphasising correct ideas from the students (Figure 6.5).

There were few teacher statements that were unintelligible and the general comments usually related to an imaginary reward that Mr Carter was going to give to the best group, treated by the students as a fun discussion.

Student Participation

Mr Carter gave instructions at each stage of the lesson and students had to wait for instructions, but, because of the pace of the lessons, students were rarely off-task. They often continued testing circuits until Mr Carter directed them to a new activity.



Note: A further 14 % of comments were general comments or unintelligible

Figure 6.6. Student utterances by category when teacher attending groups

The student management utterances usually related to circuit construction with the students also sometimes asking for more information about task management or checking on materials:

Student *Connected everything up?*
Student *Yep.*
Student *We've checked everything but it just doesn't work.*
Mr Carter *Swap. Now if that globe, if this globe's any good and that one's no good will this one still work? (Lesson 3)*

Student *So do we have to do it in the middle so everyone can reach it?*
Mr Carter *Yeah. It's one group activity. Come on let's do it. (Lesson 2)*

Nine percent of student utterances were informational statements directed to Mr Carter with students both offering general information and sharing their successes (Figure 6.6):

Student *Mr Carter, look. When you've got that like that when its only one it works but when you put this one on it stops. (Lesson 1)*

The students questions to Mr Carter were all closed and were often designed to check their understandings:

Student Mr Carter, is this lead? Because it doesn 't work. (Lesson 2)

The students were involved in developing understandings with 16% of their utterances being responses to Mr Carter's open questions and a further 12% responses to closed questions (Table 6.3). Some student offered detailed explanations that demonstrated extended knowledge:

Student Because it has to flow in a circle. It's like having a chain, when one one when one comes out through, one comes out of the battery, it pushes the one in front which pushes the one in front and so pushes one into the battery. (Lesson 1)

As in the other classes there was a high proportion of unintelligible utterances (14%) although 2% of these were again related to the imaginary reward (Figure 6.6).

Table 6.3

Types of Interactions Between Mr Carter and Students in the Group Situation

Type of utterance	Percentage of utterances from:	
	Mr Carter	Students
Managing class or group	8	3
Managing equipment	9	6
Managing task	49	37
Explanations	4	
Open questions	9	
Responses to open questions		16
Closed questions	12	2
Responses to closed questions	1	12
Information from students (conceptual)		9
Feedback	6	1
Unintelligible		12
Other	2	2

The management utterances were the largest category for both Mr Carter and the students. The next highest category for Mr Carter was questions, with a high percentage of open questions, and for the students was the responses to questions. There was also a reasonably high level of conceptual information from the students (Table 6.3).

Use of Scientific Vocabulary

The group discussions in Mr Carter's room used far less scientific language than the other classes with the only words that were used frequently being globe and battery by both Mr Carter and the students. Although the use of scientific terms was limited, the students used them more than Mr Carter reflecting the fact that the number of utterances by the students was higher than Mr Carter's. The terms were less likely to be used in discussing construction of circuits than in discussion that might develop understandings.

Discussion

The use of group work is an important part of teaching for conceptual change and development (Cosgrove & Osborne, 1985b) allowing students to have opportunities to investigate their ideas and engage in discussion with other students which may lead to the development of new understandings. It has also been suggested that this type of classroom structure also allows teachers more opportunity to interact with the students (Kempa & Ayob, 1991).

The Teachers' Interactions with Groups

In Mr Avery's and Ms Brown's classes the student and teacher utterances were similar in quantity. In Mr Carter's class the student utterances were more frequent than those of the teacher giving the students more opportunity to offer their ideas and Mr Carter more opportunity to recognise understandings that the students had.

Assertion 6/43

During teacher visits to groups, the number of interactions from the teacher and the students are usually similar in quantity although teacher utterances are generally longer.

Assertion 6/44

Where student interactions are higher than that of the teacher, the teacher has more opportunity to recognise students' understandings.

The number of teacher and student interactions related to management was higher in all the classes than those related to developing understandings. The proportion of management related interactions was less in Mr Carter's class than in the other two, indicating that he used more opportunities to facilitate the development of understandings.

Assertion 6/45

In most classes during group work, the number of utterances from teachers or students that relate to management, either of the task or of student behaviour, is higher than those related to developing understandings.

The teachers did not always follow the lesson outlines, but most group activities were completed. Mr Avery and Mr Carter both adapted the lesson outlines to suit their teaching style with Mr Avery covering all the activities and Mr Carter missing or changing some, resulting in students missing the opportunity to develop some understandings. Mr Carter's actions support Assertion 5/15 (Teachers may not recognise the effects of omitting a part of the curriculum), whereas Mr Avery's actions introduces Assertion 6/46.

Assertion 6/46

Curriculum materials may be manipulated to support a teacher's style of teaching but still maintain the integrity of the materials.

After the instructions for the task had been given, Mr Avery assisted some groups with their reading, but expected most students to follow the instructions on the worksheet, and to ask if they had problems. Ms Brown, having repeated the instructions to the class after the student had read them, also gave individual groups instructions. Mr Carter usually checked to ensure that the students knew what they were doing but, rather than give instructions, he questioned the students' understanding of the instructions. This provides further support for Assertion 5/4 (A variety of methods can be used to reinforce activity instructions, some imposed, some allowing student independence).

The initial check of all groups organised by Ms Brown and Mr Carter did ensure that all groups knew what they should be doing, but, in a supportive classroom, it should be reasonable to expect students to ask if they were unsure. Students in Mr Avery's class were expected to ask if they had difficulties and were willing to do so. This supports Assertion 5/2 (Students are more likely to participate fully where classroom environment is friendly) but also leads to Assertion 6/47.

Assertion 6/47

A quick initial check of all groups ensures students understand the task and have the correct materials.

Mr Avery was the only teacher who expected the students to progress at their own rate, with Ms Brown's students waiting for further instructions once an activity was completed and Mr Carter's lessons usually fast moving with the students progressing quickly, but *en masse*. The students in both Mr Avery's and Mr Carter's classes were generally more likely to be on-task than those in Ms Brown's class. Studies have indicated that greater learning occurs when students are on task (Ross, 1984). When students have completed their task and have nothing to do their conversation may well be unrelated to the lesson and may distract from learning. It would also fragment the lesson as the links between segments of the lesson would no longer be complete, which Berliner and Rosenshine (1977) felt could cause difficulties for primary students. This supports Assertion 5/34 (If links are not made within and between lessons, students may have more difficulty developing understandings) but also introduces Assertion 6/48.

Assertion 6/48

Student involvement in activities is increased when students are able to progress at their own rate and they become bored and off-task when they are required to wait for instructions from the teacher.

It is important that teachers monitor the groups to ensure that they are on-task and are not having difficulties (Anderson, 1984; Webb, N., 1985). All the teachers used their group visits to monitor the progress of the work in the groups, however, the teachers organised their visits differently. After circulating quickly through the groups both Ms Brown and Mr Carter then attended groups, sometimes by request, and spent some time with individual groups, often for an extended time. This meant that some groups within any group activity session did not have an extended visit by the teacher. Mr Avery usually visited most groups within the group activity time for shorter periods of time although, occasionally, he spent more time with a group that was having difficulties and he did sometimes miss one. Roychoudhery and Roth (1996) considered that teachers needed to manage the time so that all the groups had equal access to the teacher's expertise. This usually occurred in Mr Avery's class, but only in a limited way in Ms Brown's and Mr Carter's classes during the initial quick check of all groups.

Assertion 6/49

Because of the demands of supervising group work in a given class, teachers may not visit some groups which may disadvantage those groups.

All teachers at some stage either read notes the students had written or listened to their conversation to ascertain the understandings the students held and to provide a basis for discussion. Mr Avery and Ms Brown tended to read the students notes, whereas Mr Carter was more likely to listen to the group discussion. Although the students in Mr Avery's class responded well to questions and discussion conducted by the teacher, and consequently the discussions were comprehensive, those in Ms Brown's class only offered limited responses. The notes gave Ms Brown additional information which helped her manage the discussion which was, however, still limited. This introduces Assertion 6/50.

Assertion 6/50

Listening to group discussion or reading student notes enables the teacher to ascertain student understandings and pose questions to facilitate the development of ideas and understandings of students in that group.

Part of a teacher's role when visiting groups is to engage in conversation with the group; to answer or ask questions (Driver, 1989; Driver et al., 1994; Webb, N., 1985); and to help clarify the students' thinking (Cosgrove & Osborne, 1985a, 1985b). The discussion between the teachers and the students during group work was very different. Mr Avery used a small part of the group visit time to ascertain student understandings and engaged in questioning that might develop understandings. However, his conversations with groups were often used to correct constructions and sometimes to correct drawings, activities which helped develop a better understanding of circuits. Ms Brown only engaged in discussion likely to develop conceptual understandings when visiting groups in the first lesson. However, the discussions were incomplete and students may have been left with incorrect understandings. Mr Carter, in most of his group visits, listened to the students to find out what their discussion was about, and what understandings they had prior to becoming engaged in the discussion and asking questions.

One of the teacher's roles in group work is to question the students to help them reflect on their ideas and develop a better understanding (Barnes & Todd, 1977; Driver et al., 1994). Both Mr Avery and Ms Brown engaged in limited discussion that would generate conceptual understanding although Mr Avery was more inclined to use open questions than Ms Brown with both teachers also using closed questions. The students in Mr Avery's class were also more likely to offer explanations that demonstrated their

understanding supporting Assertion 5/37 (If students are able to extend their answers, more complete answers are offered and teachers have more opportunity to recognise understandings). Mr Carter tended to take on the role of facilitator (Roth, 1995). He used his group discussions to promote conceptual understanding and was successful in eliciting responses from students.

Assertion 6/51

Teacher visits to groups may be used to facilitate the development of conceptual understandings through discussion and questioning.

Mr Carter facilitated the group discussion effectively but did accept some incorrect answers from the students, resulting in groups being left with unscientific understandings, as did Ms Brown. Neither Ms Brown's nor Mr Carter's knowledge of electric circuits seemed complete and Gilbert et al. (1982) and Hashweh (1985) considered that less knowledgeable teachers may reinforce students' incorrect understandings. Although the teachers engaged in appropriate discussion it is doubtful whether much of it actually enabled the students to reach better understandings. Even Mr Avery's discussions were, on occasion, inconclusive. Ms Brown's and Mr Carter's lack of recognition of misunderstandings supports Assertion 5/25 (Teacher who lack science knowledge may accept or reinforce incorrect understandings).

Information imparted to individual groups often needs to be passed on to the whole class. This is particularly important where groups may have incorrect understandings or when the teacher's discussion with the group has resulted in an inconclusive outcome. Mr Avery ensured that anything discussed with individual groups was also discussed with the whole class, but Mr Carter did not always remember to do this and Ms Brown usually only passed on information that was related to written work. Students, therefore, had little opportunity to consider explanations developed in other groups or to ensure that their understanding was correct. Where the teacher had given a group information or explanations that would help their understanding this was not given to the other students.

Assertion 6/52

Acceptance in the group discussion of students' answers that are based on unscientific beliefs may result in students retaining incorrect understandings if the concept is not later discussed and clarified in the whole-class discussion.

Assertion 6/53

Information and ideas developed with or given to individual groups also need to be given to the whole class.

Mr Carter also used the group discussion time to review work that the students had completed previously and relate it to the current work; neither Mr Avery nor Ms Brown related past work to the current activity during small group discussions.

Assertion 6/54

Visits to groups may be used to review previous work or understandings and make links to current activities.

When the students were having difficulties with their constructions, Mr Avery tended to correct the circuits, explaining what he was doing as he worked. Ms Brown rarely assisted in the construction of circuits although she sometimes offered general suggestions and Mr Carter usually used questions to focus the students' attention on the problem. Studies have indicated that knowledgeable teachers are likely to correct students' errors in their understanding of the activities and in discussions (Dobey & Schafer, 1984) but it would appear that this might also carry over into practical activities as indicated by Mr Avery's behaviours. Although his explanations told the students what he was doing, they did not have the experience of actually constructing the correct circuits, whereas in the other two classes the students changed the circuits themselves.

Assertion 6/55

Teachers find different ways of helping students with practical tasks, some of which may allow the students more opportunity to learn than others.

There were opportunities for the teachers to suggest to the students that they could extend their investigations with students often finding one or two answers and then stopping. Mr Avery and Mr Carter encouraged the students to extend their activities with Mr Avery generally suggesting extensions to the whole class and Mr Carter to individual groups and sometimes to the whole class. Ms Brown did not suggest any extension activities. This supports Assertion 5/21 (More knowledgeable teachers are able to allow ideas and activities to be extended).

Summary

The teachers all related to the groups in different ways, with some teachers providing more opportunities for learning than others (Figure 6.7).

Mr Avery	Ms Brown	Mr Carter
Teacher and student utterances similar in quantity	Teacher and student utterances similar in quantity	Student utterances more frequent than teacher's
Expected all groups to listen to instructions and then use their sheets. If students unsure, supervised and helped with reading of sheets	Ensured all groups knew what they were supposed to be doing by frequent repetition of instructions	Ensured all groups knew what they were supposed to be doing by visiting/checking on groups with questions. Instruction given as necessary
Students expected to progress at their own pace	Students progressed as a class	Students progressed as a class but lessons were fast paced
Generally most groups visited for a limited time, although sometimes stayed with one group for a long period. Groups rarely not visited	Tended to monitor all groups quickly and then visit a limited number of groups for a longer time. In each activity session some groups were not visited	Sometimes monitored all groups quickly, then visited a limited number of groups for a longer time. In each activity session some groups were not visited
Monitored work and group processes	Monitored work and group processes	Monitored work and group processes
Limited use of group visit time to develop conceptual understanding.	Limited use of group visit time to develop conceptual understanding.	Used discussion and questioning to develop understanding
Occasionally extended and checked student understandings	Occasionally extended and checked student understandings	Extended and checked student understandings
Some use of closed questions that might develop understandings	Some use of closed questions that might develop understandings	Used closed questions that might develop understandings
Some use of open questions that might develop understandings	Very limited use of open questions	Used open questions that might develop understandings
Discussion related to conceptual understanding always completed and groups left with correct understandings	Lack of closure to discussions resulted in groups not having correct answers with groups left with incorrect understandings	Accepted incorrect statements. Lack of closure to discussions with groups left with incorrect understandings
Information given to groups also given to whole class	Information given to groups not given to whole class unless it was related to written work	When information given to groups, sometimes given to whole class
Rarely reviewed during group visits	Did not review during group visits	Reviewed previous work with groups
Teacher corrected student circuits by re-building and explaining what he was doing.	Very little help with circuit construction. Students tended to look to see what other groups were doing	Corrected student circuits by questioning students to elicit suggestions for changes and sometimes making suggestions
Did not encourage individual groups to extend investigations but asked whole class to	Did not suggest extensions to individual groups but did occasionally to whole class	Encouraged individual groups to extend their investigations
Managed behaviour problems by listening to students and redirecting them	Managed behaviour problem by use of firm reprimands	Varied responses to behaviour problems depending on circumstance
Monitored and advising groups so that all students participated	Monitored and adjusted groups so all students participated	Sometimes checked participation but not often

☐ Situations that increased opportunities for learning

☐ Situations that limited opportunities for learning

☐ Situations that inhibited opportunities for learning

Figure 6.7. Teacher interactions with groups: Opportunities for learning

Mr Carter's strategy of listening to the group conversations and then facilitating their discussion, both conceptual and practical, gave the students the chance to develop new understandings. Mr Avery also offered the students many opportunities to learn, but Ms Brown's interactions with groups tended to be limited and did not often extend the students' understanding.

Student Participation when Teachers Attended Groups

In group work, when students are expected to work cooperatively and share tasks and equipment, problems of sharing and of equal participation of students in groups may occur if students do not have the appropriate organisational skills. Generally, Mr Avery's class cooperated well but, where a problem occurred, Mr Avery listened to the students and then redirected them, occasionally using firm methods. His management was usually not intrusive and resulted in students quickly getting back on-task. Ms Brown's students were generally less cooperative and, when problems occurred, she generally used firm reprimands which were short and not intrusive. However, she eventually reorganised the class and gave structured directions to try to solve the problem. This reorganisation was successful for a time, but students reverted to their previous behaviour when not being instructed by Ms Brown. Mr Carter used a mixture of strategies, sometimes low-key strategies and sometimes very strong reprimands. His low-key strategies often passed the responsibility back to the students, with advice on how to solve the difficulty.

Assertion 6/56

Students need to be taught how to work collaboratively and to solve problems within a group situation.

Assertion 6/57

Turn-taking and cooperation in groups may be maintained by low key or strong management solutions. However, imposed management solutions may only work for a limited time.

When the teachers visited the groups, the students from all three classes questioned the teacher to check that they had the right equipment. The students in both Mr Avery's and Mr Carter's classes questioned the teacher to check their understandings and also checked that they were progressing correctly. Ms Brown's

students usually only used the teacher's visit to check that what they were doing was right.

Assertion 6/58

Students may use teacher visits to their groups to check their understandings and/or that they are working correctly on the assigned practical task.

Mr Avery's and Mr Carter's students voluntarily shared successes and general information, although this was less noticeable in Mr Carter's class. They also showed evidence of extended thinking. Few of these attributes were shown by Ms Brown's students, supporting Assertions 5/2 and 5/3 which suggest that friendly classrooms and responsive teachers result in more responsive students.

When questioned, the students from Mr Avery's class tended to offer extended responses voluntarily with those from Mr Carter's class needing some encouragement to extend their responses. The responses from Ms Brown's class were similar to those in the class discussions and were short and unelaborated. In both Mr Avery's and Mr Carter's classes some of the student questions or answers showed evidence of extended thinking or knowledge about electric circuits. Where individual students offered extra information voluntarily, the teacher had an opportunity to listen to a wider variety of student understandings than those offered during whole-class discussions. This supports Assertion 5/2 (Students are more likely to participate fully where classroom environment is friendly) and 5/37 (If students are able to extend their answers, more complete answers are offered and teachers have more opportunity to recognise understandings).

In all the classes when the teachers were at the groups, there was only limited use by teachers and students of the less common scientific terms with positive, negative and circuit being the most likely to be used. The common terms such as globe and battery were used more frequently, but mainly related to circuit construction. This supports Assertion 5/18 (Teachers may not use scientific terms consistently) and 5/42 (Students use few scientific terms).

Summary

When the information is summarised, it is apparent that the students in the classes treated the teacher visits to the groups in different ways, although there were similarities in Mr Avery and Mr Carter's classes (Figure 6.8).

Mr Avery's students	Ms Brown's students	Mr Carter's students
Some development of understandings	Little development of understandings	Engaged in discussion which might develop understandings
Used teacher visits to check equipment; sometimes to check activity; sometimes to check their understandings	Used teacher visits to check equipment; the activity; or that what they were doing was right	Used teacher visits to check equipment and sometimes to check understandings
Shared their successes with teacher voluntarily	Only shared when asked by teacher	Shared their successes with teacher voluntarily
Shared general information with teacher	No general information shared with teacher	A few students shared general information with teacher
Some questions indicated extended thinking	No evidence of extended thinking	Some questions indicated extended thinking
Offered extended responses when teacher visited	Limited responses from students when teacher visited	Offered extended responses when encouraged by teacher
Limited use of scientific language by teacher and students	Limited use of scientific language by teacher and students	Little use of scientific language by teacher and students

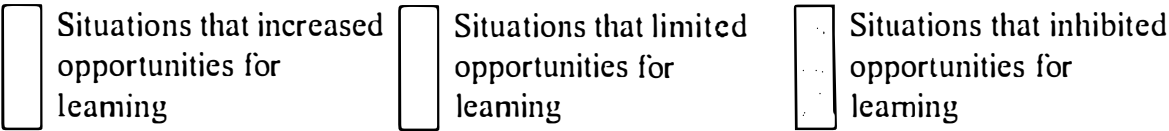


Figure 6.8. Student interactions with the teacher during group visits: Opportunities for learning

Both Mr Avery and Mr Carter’s students all participated in discussions with their teachers and offered information and ideas. Ms Brown’s students were much less likely to participate fully in the discussions and consequently, were less likely to have opportunities to change their understandings.

Having analysed the ways in which teachers interacted with students working in groups, the next chapter examines the interactions between students in the Focus Groups in the three classes.

CHAPTER 7

Interactions within Focus Groups

Overview

This Chapter is an overview of the interactions between students within the three Focus Groups during the lessons and also examines the teachers interactions with these groups. The data analysis only covers the interactions that related to the lesson and social interactions are not included, although they are discussed. Following the analysis of interactions within the three groups, the discussion relates the occurrences to assertions that have already been developed and also leads to the development of new assertions.

Mr Avery's Class

The Focus Group

Although the teachers were asked to choose average students from the class to be in the Focus Group, this group's academic ability was considered high by Mr Avery. The group consisted of three girls, Ann, Sue and Pat and two boys, Jon and Bob. When rating the students in the class, where one was high and five was low, Mr Avery considered Ann, Bob and Sue to be level one students and Pat and Jon level two students. However, their pretest scores indicate that they were not very knowledgeable about electricity, with Pat scoring equal lowest in the class and Bob and Jon scoring third lowest. Ann had the top score in the class, 19 out of a possible total of 51, and Sue was equal third highest with a score of 11. More able students, as these were, would be more likely to understand the concepts being discussed and therefore improve their scores between pre and posttests. From the discussion and work in the group it appeared that some students had some knowledge of electric circuits.

The group was intact for most lessons, although Ann missed Lesson 1a and a small part of Lesson 2 and David missed all of Lesson 4. The students worked positively as a group and generally interacted constructively with only a small amount of friction and they were good at building explanations as a group. It was a democratic group with fairly even participation, although both Bob and Pat participated less than the others. Ann or Sue tended to take the leadership role in the group although the role was not a strong one and may be better described as a leader when needed. On two occasions, each time when there was only one group member of a particular gender

present, the group was less cohesive and democratic. The first instance was during the initial set of lessons on the topic of light where Pat was the only girl in the group and was only allowed limited participation in the activities and discussions. The second occasion was during one of the electricity lessons when Boh was the only male and all three females were present and he did not participate fully in the activities or discussions.

When directed by Mr Avery, the group generally discussed the concepts under consideration and sometimes followed the instructions on the worksheet to discuss concepts. Their discussions were usually well organised with students putting their points of view but, in Lesson 1, although there was some constructive discussion in the final group discussion, it sometimes tended towards a question and answer session where one student would read a question off a sheet and another student responded, with that answer being written down. This was the only occasion that Mr Avery used photocopied question sheets.

The students tended to be independent workers and this carried over into their group work with the group progressing through the task without extra instructions.

Focus Group Use of Group Work Time

The group generally followed Mr Avery’s instructions when asked to do an activity, draw or write, or discuss topics.

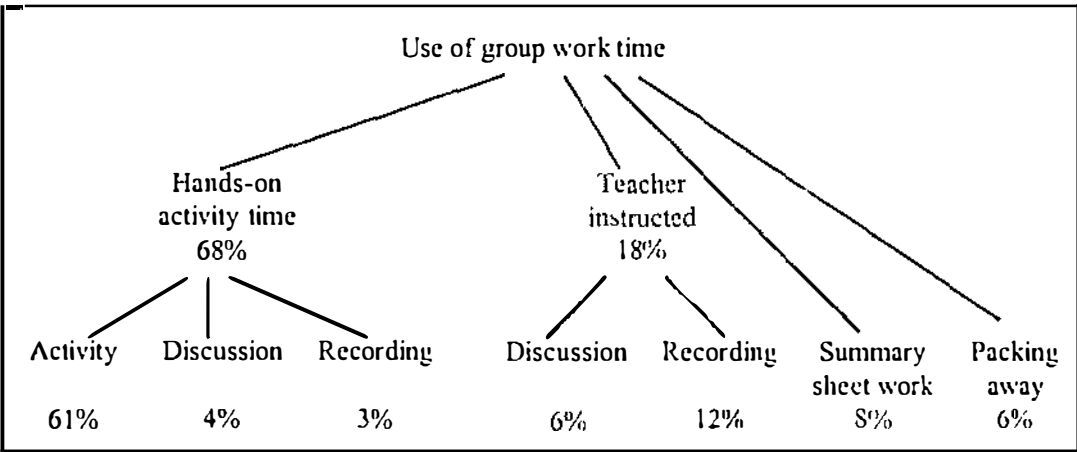


Figure 7.1 . Group activities during group work time

The group work time within the lessons was used for hands-on activity work (68% of the time), teacher instructed discussion and recording (18%), Summary Sheet work (8%) and packing away equipment (6%) (Figure 7.1). The activity work by the Focus Group included some drawing or writing about circuits they had constructed and some discussion. On some occasions only some of the students were involved in writing

or drawing activities but for seven percent of the activity time all the students were either recording or discussing as instructed by the worksheet. Discussions in this context tended to be short with none lasting more than a minute unless Mr Avery was at the group, but they generally showed evidence of development of scientific understanding.

During the first lesson, when asked to discuss a question by Mr Avery, the group members were very involved in their drawing and did not conduct the discussion, but they followed all discussion instructions after this. The amount of time allowed by Mr Avery for small group discussion was only six percent of the total group work time, mostly in the first lesson. However, the group also engaged in conceptual discussion outside of the instructed times and, when these are included, the total amount of conceptual discussion time increases to 10%. Pat, on two occasions, disagreed with comments from the group, but was overruled, once by consensus and once by a more assertive group member. Generally the group worked together to develop explanations and understandings.

The amount of teacher directed recording and writing took up 12% of the group time which increases to 15% when the recording that occurred during activity time is included. Jon did not always record when asked and his written work was limited and Bob, on one occasion, copied Sue's work. The girls' written work contained more information than either of the boys with their writing often extending into class discussion or group work times. The group completed all the activity work and all except Jon completed the written work.

Packing away equipment used 6% of the group work time but this time was sometimes also used by the girls to complete written work.

Mr Avery only completed two Summary Sheets during the lessons, with the Focus Group completing the other two soon after the lessons finished. During the lessons, 8% of the group work time was used to discuss and complete Summary Sheets, a total of 15 minutes (Figure 7.1). After the series of lessons, the Focus Group worked on Summary Sheet Number 2, related to conductors, for 15 minutes and engaged in intensive discussion; and spent five minutes on Summary Sheet Number 4, which examined their understanding of series and parallel circuits, with very little discussion.

Focus Group Work Habits

This group, as will be indicated in this discussion, were an exceptional group in their behaviours and interactions. During the group work sessions they spent most of their time working and there was limited off-task behaviour. There were some instances

of talk which was irrelevant to the task during activities or discussions but, as these were usually only one sentence comments they did not distract from the discussion and have not been included. Only off-task conversation longer than single sentences has been included in the time analysis. Over the total group work time of 153 minutes they were only engaged in social talk for 15 minutes, with the girls more likely to be involved in social conversation than the boys. On no occasion was the whole group involved in social conversation. Social conversation tended to occur when one or two of the students were constructing a circuit and the others were watching, although the conversation generally did not distract them from the activity. Apart from some teasing which was low-key and friendly, the social interactions were positive with the interactions often relating to electricity related subjects. They appeared mostly unaware of the recording equipment and, on one or two occasions when some of the students were engaged in social interactions, suddenly remembered it, but this was rare.

There were other off-task behaviours during the activity time, again usually involving students who were not actively engaged in circuit construction, although they were usually only for short periods of time. However, in Lesson 4, Ann was writing during much of the initial group work as well as during the whole-class discussion and Pat was often writing during the activities from Lesson 3 onwards. Her practical involvement with circuit construction was limited, although all group members offered overt or covert support to the circuit builders. All students generally participated in discussions with two notable exceptions. During a group discussion in Lesson 2 in which Mr Avery was involved, Sue was constructing a circuit but she was also listening at least part of the time as she did occasionally participate in the discussion. In Lesson 3, Pat was writing during a discussion about the brightness of the different voltage globes when they were connected to a 1.5 volt battery.

During the whole-class discussion times the apparent off-task behaviour was more prevalent, generally with the girls writing and the boys using equipment. However, it is not possible to state that the behaviour was totally off-task as on several occasions, although the students were doing something else, they raised their hands in response to Mr Avery's questions. Equally, on some occasions it was noticeable that a group member had not been paying attention when they were unable to respond to a question directed to them. In the review sections of the lessons sometimes the off-task behaviour was just fiddling with something from the desk which would not normally distract the student from the discussion.

Pattern and Number of Interactions Within the Focus Group

The patterns of interactions varied from lesson to lesson with students varying in the quality and number of their interactions (Figure 7.2). Generally the interactions involved short statements, many consisting of seven words or less, with very few comments being of any substantial length. Within the discussion that may have helped in developing understandings, only Ann, and on three occasions Sue, made any lengthy comments:

Sue *So she needs to have two wires, one has to be connected to there and one has to be connected to the metal shell to make it work and they've only got one connected to the bottom bit. (summarising) (Lesson 1b)*

Ann *I reckon that when we connect the third one it won't, it will be, it'll be dimmer because it won't be able to, it won't get the battery won't be out of power. That's. (Lesson 3/4a)*

Both the boys' comments were more limited although in one lesson Bob made a reasonable contribution demonstrating his understanding of the concept.

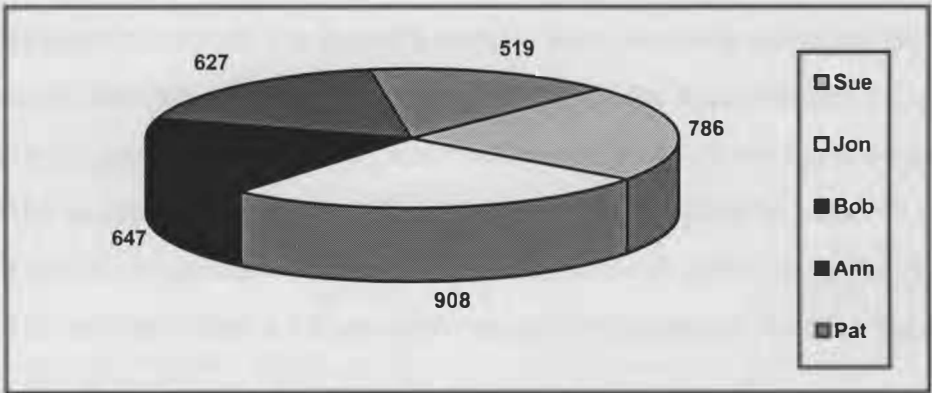


Figure 7.2. Graph showing number of utterances by Focus Group students during the series of lessons

Jon was absent for one lesson but made more comments than any other group member. He also tended to contribute more during the discussions where conceptual understandings were being developed. Ann was absent for two lessons but in the lessons attended made a higher number of contributions than Sue. Sue contributed more when Ann was absent from Lesson 1. Generally the number of contributions Bob made was low both in the whole lesson and in the development of understandings. Pat was the least likely to participate although her number of comments during development of understandings was similar to Bob's.

A quarter of Mr Avery's interactions with the group occurred when he was endeavouring to develop understandings, mostly in Lesson 2. This type of interaction did occur with other groups, but no other group had Mr Avery's attention for as long as the Focus Group had in Lesson 2. Initially he attempted to demonstrate that a globe in a circuit with one wire each side and a globe in a circuit with one wire in one side and two in the other would have similar levels of brightness. He then tried to elicit the scientific meaning of 'conductor' without success, although Ann appeared to know it.

Types of Interactions

Much of the conversation within the group centred around managing the set task and the materials with Sue and Jon often organising the activity. Being a cooperative group there were few instances where it was necessary for a student to ensure all the group members were attending, although it did happen occasionally. The discussion during the development of understandings varied. In Lesson 1a there was little conceptual discussion during the lesson but, when the students were given a sheet listing the focus questions, there was some more varied discussion. During discussions it was sometimes the most persistent voice that received the attention as when the group were discussing joins in a circuit. Pat started to explain the joins on the globe but Jon's insistence on demonstrating the battery joins resulted in Pat's contribution being lost. Sometimes the answers were built by contributions from two or more members who constructed an explanation, as when Ann initiated a learning point in Lesson 3 when, having tested the brightness of 1.3 volt, 2.6 volt and 4.8 volt globes with a 1.5 volt battery, she considered that a 4.8 volt globe should be brightest of the three tested:

- Ann *I would have thought it was the other way around.*
 Bob *No that one.*
 Pat *That one.*
 Sue *You reckon that one's the brightest.*
 Bob *No * the battery.*
 Ann *No.*
 Bob *It's only a 1.5 and that's a um 4.6 a 4.8.*
 Sue *You need by about two.*
 Bob *So you need another two batteries on that to work.*
 Ann *Oh, yeah.*
 Bob *Yes, like you see you don't that's only a that's only a 1.3.*
 Sue *You need two.*
 Bob *So that's a 1.5 it it'd be pretty good.*
 Jon *It depends on how much power.*
 Ann *Okay. (Lesson 3)*

There were some instances of the group constructing understandings outside of the discussion prescribed by Mr Avery as happened when Bob read a question off the sheet after separating the drawing pins that were part of the circuit:

- Bob* *What does this tell you about the drawing pins?*
Bob *Hey, let's do this one. Electricity can go through the drawing pins.*
Ann *Yeah that's because the metal.*
Bob *No.*
Ann *We got to do two centimetres exactly and that's why, it's so we know that it works like that when the two touch but when they. It's like unjoining the circuit.*
Sue *Exactly.*
Ann *The circuits even complete now you could even have them. Oh no, if you had them like that it'd still work*
Sue *But if they had to be like touching.*
Pat *The current is going through. (Lesson 2)*

Mr Avery reinforced this point when he visited the group.

This group used the discussion time constructively, often demonstrating the development of understandings, with all students, even if they were not active participants, generally paying attention.

The Summary Sheets elicited more discussion, with the group members building on suggested ideas. Even Summary Sheet 3 gave Ann and Sue a brief opportunity to work together to build an answer although they had been told not to discuss the sheet:

- Ann* *Because the battery voltage isn't enough.*
Sue *It's a 1.5 volt battery and it * three 1.3 volt globes, that means there are not enough electrons in the battery to light up.*
Ann *Battery.*
Ann *To light up.*
Ann *To conduct the electricity to the globes.*
Sue *Conduct.*
Ann *Mmm. (Lesson 4)*

Use and Understanding of Scientific Vocabulary

This section examines the use of scientific language by the students and Mr Avery in group discussions and discusses the Focus group students' level of understanding of science terms.

Use of scientific vocabulary

The only words that were frequently used by the group and by Mr Avery during his group visits, were battery and globe, and these were usually used in relation to circuit construction. Circuit was a term that was used by students in the earlier lessons.

but less so in later ones, although it was frequently used by Mr Avery. Some words which had been used in whole-class discussions were not used by the group. These included filament, insulator, resistance and terminal. Positive and negative were used to explain circuit flow in Lesson 1, but were used infrequently after that. Other words which were used infrequently in the group were conductor, energy and electron. Generally, the use of scientific vocabulary was limited during group work.

Understanding of scientific vocabulary

Ann and Sue had the most comprehensive understanding of scientific terms, although neither was able to offer an explanation for terminals and resistance, both of which were not clearly explained by Mr Avery. Jon's understanding was also of a high level and, although he could explain resistance and terminals, he was unable to offer a meaning for conductors and insulators, which, again, were poorly explained by Mr Avery. Bob was unable to offer explanations for all the terms listed so far, but also had difficulty with filament, which only had a limited explanation from Mr Avery, and circuit, which only had a limited explanation, but which was used frequently in whole-class discussions. Pat had the poorest understanding with many of her explanations very limited.

Ms Brown's Class

The Focus Group

This group consisted of two boys, Neil and Ryan, and two girls, Tina and Katy. Ms Brown chose students with quite high academic ability for the group, with Neil being rated at level one/two and the other three students at level two. Their pre-test scores indicated their varying levels of knowledge about electricity, with Neil coming third in the class of 32 with a score of 20 out of a total possible score of 51; Katy coming equal eleventh with a score of 11; Ryan coming equal sixteenth with a score of six and Tina next to lowest with a score of two. The highest score in the class was 24. More able students, as these were, would be more likely to understand new concepts and therefore improve their scores between pre and posttests. Neil had some knowledge of electric circuits and Ryan's and Katy's comments indicated some understandings that were not demonstrated in the pretests.

The group was intact for most lessons with the only absence being Neil in Lesson 3. The group were reasonably cooperative although Tina did tend to get omitted from activities and conversation and sometimes her contributions were not well

accepted by the other members. However, she did appear to listen and pay attention. She seemed to relate better to Neil than Ryan and Katy, and seemed very isolated in the week Neil was absent. Neil, Ryan and Katy constructed most of the circuits. Even when Ms Brown organised the groups so that all students would participate, Tina did very little and, when she was building, the other students tended to take over and complete the task. Ms Brown rarely gave the groups instructions to discuss topics and the group was not one that usually discussed in much detail outside the teacher imposed discussions. Neil tended to lead the group in the activities, but he was also the person who reminded the others to follow the instructions, for example, to predict results prior to testing. He was not an intrusive leader, but the other group members turned to him for help and advice. During the lesson when Neil was absent, Ryan tended to be the leader in the construction activities, although not in any other areas.

The group generally followed Ms Brown's instructions, and was reluctant to move on to another section of the worksheet if they had not been told to do so, as demonstrated when they had finished responding to the first section of the Summary Sheet in Lesson 1:

Ryan *Now we've got to work out um a better way I mean to make it work.*
Katy *Do we do that?*
Neil *I thought we were just waiting.* (Lesson 1)

Focus Group Use of Group Work Time

The group work time within the lessons was used for hands-on activity work (61% of the time), teacher instructed discussion and recording (7%), Summary Sheet work (29%) and packing away equipment (3%) (Figure 7.3).

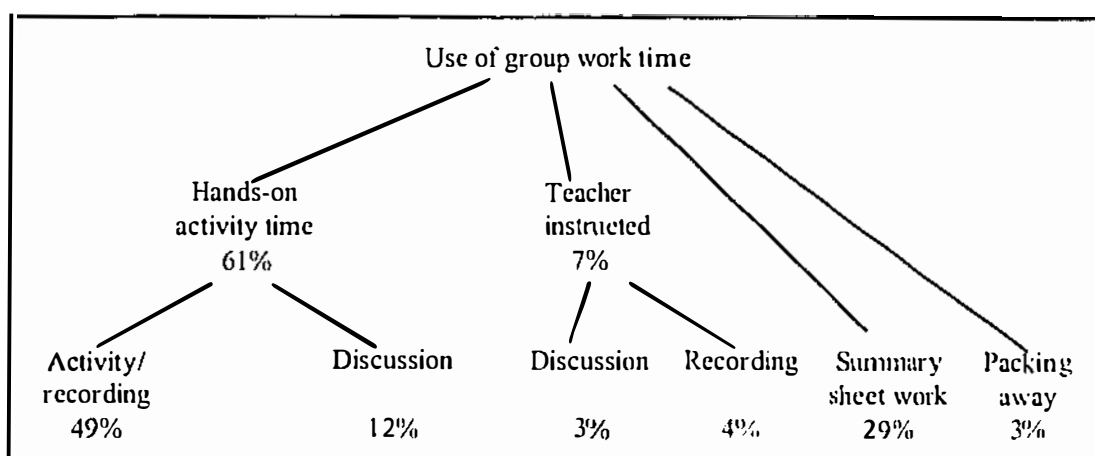


Figure 7.3. Group activities during group work time

Usually the Focus Group completed the activity work but in the week that Neil was absent they did get behind and missed two activities. They were only occasionally told by Ms Brown to do written work, usually when it was necessary to get diagrams drawn or predictions written down, and the group followed these instructions. Apart from in the first lesson when the students were asked to discuss the direction of current flow in a circuit, the students were not specifically asked to discuss anything. However, the Focus Group often discussed incidentally although this discussion tended to be fairly superficial. Of the total group activity time the Focus Group spent 15% in some form of conceptual discussion, although, because of the differing opinions of the group members, consensus was difficult to attain. Any writing tended to be incorporated into the activity with the group following any instructions for recording as they progressed through the activity. Ryan was least likely to get started on the written work and tended to copy from Katy or Neil. All group members produced similar amounts of written work completing most of the requested work.

A considerable proportion of the group work time (29%) was used to complete the Summary Sheets. Ms Brown often did not allow the students to discuss these but the group did tend to work together on them and discuss them. However, as with other tasks, they spent some of this time socialising whilst waiting for further instructions.

Only a small amount of time was spent packing away and the group worked together on this (Figure 7.3).

Focus Group Work Habits

During the group work time the group members spent much of the time working although 10% of the time was used for social discussion in which they were all involved. Ryan and Katy were also inclined to chat socially outside of this 10% taking up another 4% of the time, although it is difficult to assess how much their conversation was distracting them from the activities, as they sometimes engaged in social conversation when constructing circuits. During the group discussions Neil, Ryan and Katy dominated the conversation. Tina contributed little although she was usually attentive. Generally the interactions were positive with some teasing although this did not appear to be negative. There were few other off-task behaviours when they were working as a group, although sometimes a student would be fiddling with equipment that was not being used during activities or writing.

Neil, Ryan and Katy also dominated the circuit building with Tina watching. The students who were not actually engaged in the building often watched closely and would make suggestions and offer help.

During the whole-class discussion time only Neil was likely to be paying attention most of the time although he was sometimes off-task. During the last lesson the group constructed their circuit incorrectly and, for part of the discussion time, Neil was attempting to rebuild it. Ryan and Katy were least likely to pay attention, frequently talking quietly or using the equipment, sometimes also distracting Tina. During Lesson 3, when Neil was absent, they were off-task for most of the whole-class discussion time. Tina was less likely to be off task than Ryan and Katy but, again during Lesson 3, was distracted by the others. The group were often not attending when other students were drawing on the blackboard, and this was noticeable in all lessons.

Patterns and Numbers of Interactions Within the Focus Group

The patterns of interactions varied from lesson to lesson with students varying in the quality and number of their interactions (Figure 7.4). Generally the interactions within the group were short with many being less than 10 words. Often longer statements were related to the construction activities when students were giving others instructions, although a few occurred during conceptual discussion:

- Ryan

Fourth wire, fourth wire, fourth wire, fourth wire. Right we need, you always need one more wire than we have of batteries. (Lesson 3)
- Katy

*Because you've got to have the wire connecting to both sides that's why I though you needed two wires. Like you can do it with two wires but otherwise you have to do it with one wire so ***. Did you get that?*
(Lesson 1)

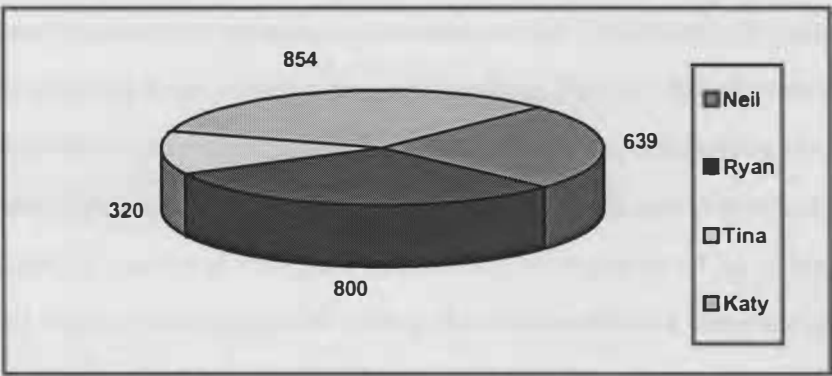


Figure 7.4. Graph showing number of utterances by Focus Group students during the series of lessons

Tina was least likely to make substantial contributions during any discussion, including conceptual discussions. During most of the lessons Neil, Ryan and Katy made similar contributions, however, during Lesson 4, Neil's contributions were more frequent than any other group member. Neil was absent for one lesson and his total interactions were about three-quarters of Ryan's or Katy's. He also contributed more to the conceptual discussion than any other group member. Ryan and Katy had similar numbers of interactions during both the activity and conceptual work.

Ms Brown generally only attended the group for brief periods of time, usually checking on their progress. She spent just over two minutes with them in the second lesson, when the group had several globes that had been blown, trying to ascertain why the circuit was not working. She spent a further 30 seconds with them later in the lesson, conducting a discussion intended to show that the galvanised wire was not a good conductor:

<i>Ms Brown</i>	<i>Did it work?</i>
<i>Students</i>	<i>Yeah.</i>
<i>Ms Brown</i>	<i>When you put it around.</i>
<i>Tina</i>	<i>Yeah. You were here when we showed you.</i>
<i>Ms Brown</i>	<i>Right. It worked that time that time. Now,</i>
<i>Neil</i>	<i>It flickered</i>
<i>Ms Brown</i>	<i>Ah.</i>
<i>Ryan</i>	<i>You've got to push it together like that.</i>
<i>Ms Brown</i>	<i>Okay, it fluctuates a little bit.</i>
<i>Katy</i>	<i>Yeah.</i>
<i>Ms Brown</i>	<i>Sometimes it works, sometimes it doesn't.</i>
<i>Ryan</i>	<i>Yeah. (Lesson 2)</i>

Types of Interactions

There were few attempts by any group members to ensure that all the group were watching activities or participating in discussions with individuals or pairs of students sometimes working when others were not attending. Most of the conversation in the group was related to managing the activity work, with any conceptual discussion being limited. Neil, Ryan and Katy dominated any activity work and discussion. Tina did offer some suggestions, and was very concerned when she considered the group had constructed the incorrect circuit for testing the conductors and insulators in Lesson 2, and tried to encourage the group to change their circuit:

<i>Tina</i>	<i>We've got to do this. We've got to use this.</i>
<i>Neil</i>	<i>No, we don't.</i>
<i>Katy</i>	<i>I don't care.</i>

Tina (Reading) *Okay. Now you're going to try to make it work again. You have a variety of things supplied that you can use to connect the two drawing pins.*

Neil *I don't care.*

Tina *Read your instructions. (Lesson 2)*

The amount of discussion within lessons that developed understandings varied considerably from lesson to lesson, with Lessons 1 and 4 having the most discussion. In Lessons 2 and 3 students were asked to make and write down predictions but the only teacher directed discussion time was related to the Summary Sheets in Lesson 2. Often the discussions were inconclusive and this was demonstrated in Lesson 1 when the groups were directed by Ms Brown to discuss the direction of current flow:

Ryan *** it went through the wire.*

Neil *It went through the positive.*

Ryan *Yeah. Up his bum. (giggles)*

Neil *It didn't, it went, okay so it went out there, I reckon*

Katy *Out there? Out there? Out there? But it's going to reach the globe, it doesn't move the opposite way.*

Neil *Doesn't it go out the positive?*

Ryan *Which one's the positive?*

Katy *Wouldn't it go out the negative?*

Neil *Isn't there a certain way it goes?*

Tina *Doesn't it goes through the positive and out the negative?*

The group then discussed where the positive and negative terminals of the batteries were and then continued discussing the direction of current flow:

Ryan *So what do you draw?*

Neil *From positive to negative.*

Katy *So was that out the positive in the negative?*

Ryan *In the negative.*

Ryan *It can't go out the positive. Yeah I suppose it could.*

Katy *(giggles)*

Ryan *Really technically it could,*

Neil *It could go out the negative but.*

Ryan *I don't.*

Katy *We only think it goes out the positive and in the negative.*

Ryan *That's a point.*

Neil *It does, doesn't it?*

Ryan **** it couldn't. Generating through the battery, it just goes all ways. It goes clockwise.*

Neil *Clockwise! Well it could go clockwise that way.*

Ryan *(giggles) * only one way.*

Katy *Okay, so it's going this way. Is that right? No it's going the opposite. Oh you idiots.*

Ryan *What was I wrong?*

Katy No, I think you're right, but what's Neil done? He's doing half of his arrows one way and half the other. (Lesson 1)

Neil actually drew his arrows going from positive to negative.

In Lesson 4 they followed some of the instructions on the sheet and predicted and discussed and there were also instructions from Ms Brown to discuss parts of the lesson. Much of the discussion involved controversy about the brightness of the globes in parallel circuits with students unable to agree whether they became brighter when one was removed:

Katy They go dimmer. They go dimmer.
Ryan It's brighter now.
student No they're dimmer.
Neil I reckon they're the same.
Katy That one's the same but that one's dim.
Neil Yeah.
Katy That's the same voltage.
Neil I'm not so sure.
Katy Maybe it's because they had travel through that, I don't know.
Neil That's a a little globe holder.
Ryan Speed of light.
Katy Now they're all the same sort of, well, maybe.
Neil You don't know what you're what you're talking about.
Neil There it goes.
Neil Hey, look! It went brighter. Watch this. See it go brighter.
Katy Yeah, That one, that one. That one did and that one. that one goes dimmer and that one goes brighter.
Ryan It does not.
Katy No, that one stays the same and that one goes brighter. (Lesson 4)

In the first lesson there was some discussion about the joining points in the circuit although there was no overt demonstration of understanding, just instructions how a circuit needed to be constructed. Much of the conceptual discussion related to the way circuits were constructed with little discussion of why things were happening:

Neil No, that one has to go on the bottom. One has to go on the side. One has to go on the bottom
Katy How do you know?
Neil That's how it works. Cos my sister does it. No, on the bottom grey bit.
Tina It didn't work.
Ryan Is it on?
*Katy No. Hold the *. Somebody's got to put it on the this little silver bit down there.*
Katy On the black bit.
Ryan Tina, hold the black bit I'll hold this one. (Lesson 1)

Generally the group's discussions relating to the Summary Sheets did not involve much conceptual understanding but did refer back to the activities in the lesson, using those to supply answers to the questions. In Lesson 2, when the students were asked to discuss how the Summary Sheet problem could be solved, the group initially asked Neil what to do, although Katy did offer another solution and checked with Neil to see if it would work. The discussions tended to be argumentative rather than constructive:

Ryan *She needs she needs three 1.3 volt globes.*
 Katy *With three batteries.*
 Tina *Four batteries.*
 Katy *Three.*
 s *Three.*
 Tina *Four.*
 Ryan *We've only got three.*
 Katy *Three, because four'd blow it up.*
 Tina *Three 1.5 batteries, right. Only uses the three three 1.3 volts as opposed to 3.6.*
 Ryan *Three 1.4.*
 Katy *Because 1.5 is 4.*
 Katy *1.5.*
 s *1.5, so we've got 4. 5 in three batteries.*
 Ryan *Have three 1.3 equals 3.*
 Katy *Equals 4.5. (Lesson 3)*

There was little evidence of students building on each others understandings, although it happened occasionally. In Lesson 4 the students had difficulty completing the Summary Sheet and they together generated an interesting answer that did not answer the question and used science terms that were not understood:

Neil *Jo has to make a parallel circuit. (writing)*
 Neil *How're we going to write stuff on that.*
 Neil *Parallel circuit. But they all have to be on top.*
 Tina *She said, she said we have to make a parallel circuit so we have to make a parallel circuit.*
 Neil *But I don't know what to write about it.*
 Ryan *Say she will have to change her simple circuit to a parallel circuit. That's what I put.*
 Neil *That's what I wrote.*
 Katy *Therefore it won't use as much energy so*
 Neil *So the the light will save energy so*
 Ryan *uh By using the parallel circuit*
 Katy *The battery will*
 Neil *So there will be conservation of energy.*
 Ryan *Yeah, by using the parallel circuit energy is conserved.*
 Neil *That's right.*

Neil A parallel circuit saves energy.
Katy Why does it save energy?
Neil I don't know, I don't know.
Katy (Writing) She needs to connect the wires each globe so. Oah, how do you
make a parallel circuit? (Lesson 4)

Ms Brown did not use her visits to the Focus Group to develop understandings.

Use and Understanding of Scientific Vocabulary

This section examines the use of scientific language by the students and Ms Brown in group discussions and discusses the Focus group students' level of understanding of science terms.

Use of scientific vocabulary

Ms Brown was rarely involved with discussion with the Focus Group and the only terms she used in her interactions were battery and globe with one mention of circuit.

The terms that were in frequent use during the group discussion were battery, globe, positive and negative and these were usually used when constructing circuits. Circuit was a term that was used in all lessons, but not to the extent of the previous group of terms, and was used as a label describing what had been constructed. 'Current' and 'electron' were terms which were used in whole-class discussions but were not used in the group. The use of the term 'electron' was limited in the whole-class discussions and mainly used in the first lesson. Some terms, such as conductor and insulator were only used in the lesson in which they were introduced (Lesson 2), with insulator used very little. These terms were also only used by Ms Brown in Lesson 2. 'Parallel' to describe a circuit was used during Lesson 4 when the students were trying to complete the Summary Sheet, but 'series' was not used at all. Generally, the use of scientific vocabulary was limited during group work and tended to be used to name objects.

Understanding of scientific vocabulary

Neil had the most comprehensive understanding of scientific terms, although he only offered a poor explanation for globe and energy. The term 'globe' was not explained by Ms Brown, although most students would have an everyday explanation for it, and 'energy' was only explained incidentally. Ryan was unable to explain the terms 'globe', 'energy' and 'electrons'. Tina and Katy demonstrated the least understanding with many of their explanations very limited.

Mr Carter's Class

The Focus Group

Mr Carter chose students with a range of abilities for the Focus Group which consisted of two boys, Geoff and Colin, and two girls, Linda and Helen. When rating the academic ability of the students in the class, where one was high and five was low, Mr Carter considered Geoff to be level one, Linda level two and Colin and Helen level three. The pretest scores for the students indicate that they were generally not very knowledgeable about electricity. Colin was eighth in the class with a score of 16; Geoff came fourteenth scoring 10; Helen came 21st in the class with a score of eight; and Linda scored second lowest in the class, with a score of four out of a possible total of 51. The highest score in the class was 29. More able students, as Geoff and Linda were, would be more likely to understand the concepts being discussed and therefore improve their scores between pre and posttests. Initially it appeared that the students in the Focus Group had little knowledge about electric circuits, but Geoff made some comments that indicated that he knew more than was indicated by the pretest and interview, although he did not share his knowledge with the group.

The group was intact for two of the four electricity lessons, with Colin being absent for the first lesson, and Linda away for the third lesson. On each occasion, Mr Carter replaced the missing student with another student from the class. For the first electricity lesson Colin was replaced by Allen, a student who appeared knowledgeable about electricity, but who had some idiosyncratic ideas. On the second occasion, Linda was replaced by Fiona, a quiet but knowledgeable student. Both of these students were rated level one in ability and both gained high scores in the pretest with Allen being top of the class with a score of 29 and Fiona third with a score of 23. The Focus Group lacked cohesion and the students were not cooperative, finding it difficult to interact positively. There were many negative comments and some name calling during their discussions. They found it very difficult to stay focussed on any given task, with Geoff often being the student who led the conversation into other areas, and with their social conversations being wide ranging often with negative connotations.

During the first lesson Helen and Linda worked together and Geoff and Allen both worked by themselves. After this there was little cooperation in the activities with one student often doing the work and the others talking socially.

Most discussions held by the group were superficial with the only quality discussions involving all the students occurring when Mr Carter intervened. In Lesson 1 he elicited the correct explanation of the flow of current in a circuit, mainly from Allen and then asked Allen to attempt to explain to the rest of the group. Both the discussion and the explanations were constructive although Geoff's attitude was negative. In the last lesson the discussion with Mr Carter during the group activity time was of a high quality and demonstrated the development of understandings (pp. 146 -147), but the quality of the discussion when Mr Carter left reverted to a low level. Prior to completing Summary Sheets Mr Carter usually gave groups the list of focus questions that were in the lesson outlines, intending these as a focus for group discussion. This time was poorly used by the students in the Focus Group and, rather than attempting to develop understandings, they answered the questions with little thought. Geoff, Colin and Linda tended to be involved in the discussions with Helen only occasionally contributing. However, all of the group, at some stage, did not participate.

There was no one student who appeared to be the leader in the group, although Colin often did the circuit building, sometimes whilst the others were chatting socially. Helen seemed more isolated within the group than the others and was less likely to participate. Generally this group showed little evidence of independent work, neither following instructions effectively nor working on their own.

Focus Group Use of Group Work Time

The group work time within the lessons was intended to be used for hands-on activity work (35% of the time), teacher instructed discussion and recording (16%), Summary Sheet work (46%) and packing away equipment (3%) (Figure 7.5).

The group rarely followed in full Mr Carter's instructions to do an activity, draw or write or discuss a topic. They would sometimes do the work, but it was often at a minimal level and the discussions were usually brief, often just at a question and answer level, with little discussion about the answers and assuming that the first answer offered was right. Occasionally there was some limited discussion but there was often a negative feeling about the interactions. Generally the discussions or questions and answers were very brief, with the only longer discussions occurring when Mr Carter attended the group. When asked to discuss the lesson at the end of Lesson 2, the group did not discuss science at all.

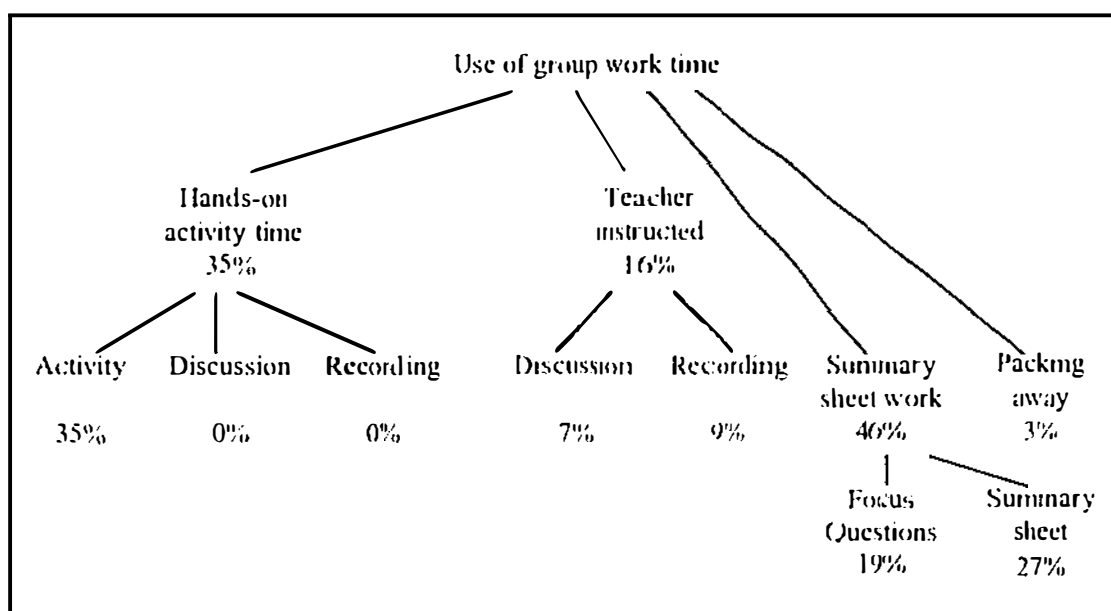


Figure 7.5. Group activities during group work time

As will be discussed in the next section, the amount of time this group actually spent on the activities and discussion was considerably less than the amount allowed because of their high level of off-task behaviours. During the hands-on activity time there was minimal conceptual discussion, and, although the worksheets included recording, the students only recorded when they were reminded by Mr Carter. In Lesson 1, Allen made some comments that, with more discussion, may have engendered some understanding, but these were not followed up by the other group members. An example of the students' poor use of discussion time shows that, in a 15 minute segment of discussion that occurred in Lesson 1, the group only spent 40 seconds in voluntary discussion, with a further two minutes of discussion when Mr Carter attended the group and slightly more than two minutes used by Allen to explain current flow to the group at Mr Carter's request.

In Lesson 1 all the Focus Group students looked at Allen's recording and copied his work. In the other lessons Linda and Helen usually did some recording with both Geoff and Colin copying their work.

The amount of teacher directed discussion which should have taken place was quite high when both the general discussions (7%) and the discussions around the focus questions (19%) are considered. Because of the lack of whole-class discussion of most of the focus questions, and the Focus Group's limited responses to the questions and poor use of discussion time, the group would have been left with many

misunderstandings or limited understandings. When discussing the way a series circuit was constructed the responses were very limited:

Colin (reading) *Is the circuit similar to the circuit you find in your torches?*
Geoff *Yes, because.*
Fiona *The battery is connected to a light globe.*
Colin *How?*
Fiona *Because the battery's connected to the light globe. (Lesson 3)*

When the students were working with the focus questions, it was often the student who read the question who also answered it:

Colin/Linda *What was needed to construct the model?*
Geoff *I don't care.*
Helen *What was that Geoff?*
Geoff *Some wires, a globe, a battery.*
Linda *Yeah, that'll do.*
Colin *How were the batteries connected? By alligator clips. And a lucky band (Lesson 4)*

The proportion of time for completion of Summary Sheets was also high at 27%, but nearly half of this time was in the first lesson where they had nearly an extra hour's working time, which was supposed to be used to discuss the focus questions and work on the Summary Sheet. The Focus Group only discussed the topics for just under 12 minutes, with two minutes of this time occurring when Mr Carter attended to the group and another two minutes used by Allen explaining how batteries worked at Mr Carter's request. As usual, the responses to questions were very limited. Where time was allowed in the lesson for specific discussion of the Summary Sheet, the students relied on one student to supply the appropriate answers and there was no real discussion:

Linda *What does it need, Allen? What does it need?*
Allen *It just needs the wire going from the back of the battery back through to the globe or from here from the other terminal of the battery. (Lesson 1)*

Only one Summary Sheet was completed during the lesson; one was completed for homework and, as there are no records of how long the students would have taken, the time has not been included in the totals; and the other two were completed in class time after the science lesson during which time there was no discussion beyond any that had occurred during the science lesson, which, for the Focus Group, was negligible.

Only 3% of the total time was used for packing away and this tended to be acrimonious, with arguments as to who was to return the student kit. On one occasion, nobody returned the kit and it was left on the desk.

Focus Group Work Habits

During the group work sessions the group were frequently off-task. The amount of time spent on social interactions was high and there were constant verbal interruptions to the flow of work within the group. During Lesson 1, there were 40 interruptions during group activity time, when all the group were distracted. Frequently all the group members were involved in social conversation, although sometimes one member, either Colin or Linda, would be constructing a circuit with the other members not paying any attention. During the total lesson time of just over six hours, the whole group was engaged in social interactions for nearly one quarter of the time (78 minutes) with off-task conversations occurring across all types of activities.

Geoff was the student most likely to be off-task, usually talking but sometimes doing nothing although not attending. Although conversation was the most common off-task behaviour, students also sometimes used the equipment, often inappropriately, or were sometimes writing.

During the whole-class discussion time it was rare for all the group to be paying attention at the same time. Linda and Helen needed to turn to face the blackboard and they were more likely to pay attention. However, it was often intermittent with both frequently turning back to their desks. When the whole-class discussion was long they sometimes held quiet conversations and they were occasionally drawn in to Geoff and Colin's conversations. Linda was sometimes writing during the discussion time but generally the girls' off-task behaviour involved watching what Geoff and/or Colin were doing. In Lesson 1, because of their off-task behaviours, the group did not complete some of the activities and, when asked to raise hands to indicate whether circuits worked or not they looked to see how Allen was responding and copied him. Geoff and Colin spent much of the whole-class discussion time off-task, either talking, using the equipment, often inappropriately, or just gazing around.

When instructed to test circuits the students often did not do so. When the whole class was questioned afterwards, they would follow the class and raise their hands when most class members raised their hands in response to the teacher's question.

Pattern and Number of Interactions Within the Focus Group

The patterns of task related interactions within the lessons varied. In Lesson 1 Allen, the replacement group member, dominated the interactions in the discussions and Fiona, in Lesson 3, had a similar number of interactions as Helen. In Lesson 1, Helen's contributions were high and were close to Geoff's and Linda's. Usually Geoff, Colin

and Linda produced a similar number of statements, with Helen’s contributions being about a third of this number (Figure 7.6). The length of student contributions was usually less than 10 words, although in Lesson 1, Allen made some longer statements.

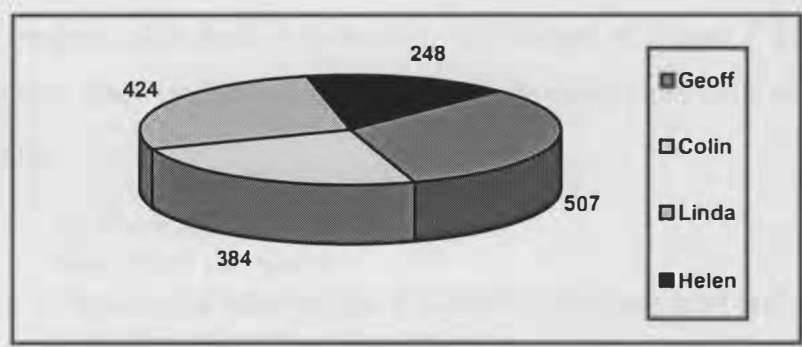


Figure 7.6. Graph showing number of utterances by Focus Group students during the series of lessons

Student contributions varied from lesson to lesson rather more than the other groups studied, with Linda making more contributions in Lesson 2, and Geoff in Lesson 3 when he commented about the flashing globes. During this lesson, Geoff also told the group why three globes in series would not work well, engaging in no discussion. The conversation then became social and, when Helen tried to bring the conversation back to the topic of discussion, Geoff considered that it had been discussed:

Geoff *We’ve already discussed it. There’s not enough energy coming from the 1.5 volt battery to go round three 1.3 volt globes. (Lesson 3)*

Mr Carter held discussions with this group in Lesson 1 and Lesson 4. On both occasions he elicited some quality discussion from the group. The amount of time spent with the group was similar to that spent with some other groups, although he did spend more time with them than with others in the last lesson.

Types of Interactions

Although some interactions related to managing the task, these were limited and the majority of group interactions were social. There was little constructive discussion within the group and many interactions had negative connotations:

Colin *What do we have to write here?*
Linda *You can do it yourself.*
(Colin tries to grab Linda’s file)
Linda *Colin!*
Colin *Ah, cool.*
Linda *You’re so dumb.*
Helen *Shut up, Geoff.*

Linda *You're so dumb, Colin. You can't even figure out what to write. It's a bit obvious. Now you've crumpled my file.*
Colin *(Writing) Second brightest.*
Geoff *I haven't written anything. ** fail. It would be bad. (Short pause) I don't care. (Lesson 2)*

The students often worked by themselves although in Lesson 1, Linda and Helen worked together. They tended to collect the materials needed and build circuits with little discussion:

Helen *We'll use this *.*
Linda *Yeah. We'll use yours.*
Linda *I'll put it, I'll hold it here. You put it on the gold part and I'll hold it there. No I might get electrocuted.*
Allen *No, you won't. You won't even feel anything.*
 Girls connected circuit
Linda *Well, it doesn't work does it. (Lesson 1)*

When Mr Carter visited the group, the girls were able to demonstrate one working circuit and one that did not work.

Colin was the student most likely to be involved in constructing circuits but when he did so the other students often took little notice as was the case in Lesson 4 when he had succeeded in building the requested circuit:

Colin *Done it! Everyone, I have done it! (Lesson 4)*

The other students in the group were involved in social conversation and ignored him.

The amount of discussion that might develop understandings was very limited but occasionally occurred, sometimes with one person giving the answer as described, and on other occasions there was some limited evidence of the group building on each other's input, although this was rare:

Linda *We have to write a sentence about conductors.*
Geoff *It's it's metal*
Linda ***
Geoff *All conductors are metal.*
Linda *No they're not, they're not all metal*
Geoff *Yes, they are.*
Linda *They contain. They're metallic.*

Social conversation

Linda *No, we've all got to write the same sentence here. Okay. Move your arm, Geoff. (Pause) Move your arm, Geoff. Excuse me, Geoff. Can you please move your arm? (Pause) All conductors have some metal in them.*
Geoff *Metallic.*
Helen *No, we want.*
Linda *Yeah, because you're a, all all conductors have.*

Colin	<i>Stop playing with things.</i>
Linda	<i>All conductors. All conductors have metal in them so that the electricity</i>
Colin	<i>Right.</i>
Linda	<i>So that the electrons can flow through them. (Lesson 2)</i>

Mr Carter did not ask the students to discuss the Summary Sheets *per se* but would ask them to answer the focus questions for the lesson and sometimes discuss what they did in the lesson. As described previously, this discussion was very limited.

Use and Understanding of Scientific Vocabulary

This section examines the use of scientific language by the students and Mr Carter in group discussions and discusses the Focus group students' level of understanding of science terms.

Use of scientific vocabulary

Because of the limited science discussion that occurred in this group, the use of scientific terms was low, and was often related to the focus questions. Battery and globe were used during the construction of circuits, and battery was used frequently by Allen during his descriptions in Lesson 1. The terms 'electric current' or 'current' were not used at all by the group. Several terms, conductor, insulator, terminal, positive and negative, were only used in the lesson in which they were introduced, with other terms such as 'electron' and 'energy' used infrequently. Mr Carter only used a few terms when interacting with the group with 'globe' and 'circuit' being the most common.

Understanding of scientific vocabulary

None of the students were able to explain the terms 'series' and 'parallel' as they relate to circuits and both terms were not clearly explained by Mr Carter. Geoff had the most comprehensive understanding of scientific terms with the only terms he could not explain being 'energy' and 'terminals' although his explanation of 'switch' was limited. Colin managed to explain half of the terms well, but was unable to offer any explanation for 'switch', 'terminal' and 'electrons'. His explanations of the remaining terms was limited. Linda also managed to explain half the terms well, but was unable to explain energy, positive and negative, and offered limited explanations for other terms. Helen had the poorest understanding and was unable to offer any explanation for switch, energy, terminals or electrons, with most of her other explanations very limited.

Discussion

The students chosen for the Focus groups were similar in ability although Mr Carter's class included some lower rated students than the other two classes.

Kempa and Ayoh (1995) found that students in secondary schools involved in group work did not necessarily impart all their understandings to the other group members although they did not suggest why this might be so. In each of the Focus Groups there was at least one student who had some knowledge of electric circuits and who scored reasonably well on the pretest. In both Mr Avery's and Ms Brown's groups these understandings were offered to other members of the group to assist in construction of circuits or development of understandings. It was usually offered in a helpful, rather than dictatorial, way. In Mr Carter's group information was rarely offered and, when offered, was presented in a dictatorial manner that precluded further discussion. Geoff, the student who appeared to have some understanding of electric circuits, did not complete enough individual work to ascertain whether there were ideas that he did not impart.

Assertion 7/59

Students with a greater knowledge of the topic than other group members may offer their information or ideas in a helpful or a dictatorial manner which may affect the development of understanding.

Kempa and Ayob, (1991), Tao and Gunstone (1997) and Noreen Webb (1985) explained that, when working collaboratively, students need to work together to complete tasks and they are expected to interact together to solve any difficulties and provide help within the group. Kempa and Ayob (1991) also stated that students need to be able to work independently. The Focus Groups varied in their group dynamics with Mr Avery's group being cohesive and cooperative; Ms Brown's group reasonably cohesive although it was less so when Neil was away; and Mr Carter's group being very uncooperative and negative. It is unlikely that, in a normal teaching situation, Mr Carter's group would have been left together but, because of the study, Mr Carter did not change the composition of the group. He did include different students when group members were away which made no difference to the group dynamics. This supports Assertion 6/56 (Students needs skills to work collaboratively and solve problems in groups) but also introduces Assertion 7/60

Assertion 7/60

The choice of students to work together in groups needs to be planned carefully to avoid dysfunctional groups.

The emergence of a leader within a group appears to assist in collaborative learning with both Mr Avery's and Ms Brown's groups producing leaders that helped keep the groups on track. The lack of a leader in Mr Carter's group may have been a factor in the lack of cooperation and the limited work that was produced. Both Brown and Palinscar (1989) and Richmond and Strlely (1996) recognised the leadership role that could occur in groups with the latter describing three types: the inclusive leader, the persuasive leader and the alienating leader. The students who took the leadership role in Mr Avery's class acted mainly as inclusive leaders, whereas the student who took the main leadership role in Ms Brown's class did not fit any of these categories but fits a new category of "unassuming". He tended to get on with the task and question understandings in a rather quiet, unobtrusive way.

Assertion 7/61

A student may direct the group in an unobtrusive manner but still have the role of leader.

Assertion 7/62

The presence of a leader in a group, even if this role is rotated between students, facilitates group work.

Studies (Kahle & Lakes, 1983; Whyte, 1984) have indicated that boys tend to dominate equipment use in science lessons, doing most of the activity work. In Mr Avery's and Ms Brown's classes, although the students shared the activities, the students in each group with the lowest score on the pretest, Pat and Lisa, were not as involved in using the equipment. There seemed to be no situations where the tasks were shared fairly in Mr Carter's class although, once again, the student with the lowest score on the pretest had little involvement with the hands-on activities. Although it was one of the lower ability students in each group who did not participate as effectively, there may have been different reasons for their lack of participation. It sometimes seemed to be because of pressure within the group where other group members limited a student's input, but, with Helen in Mr Carter's group, it appeared to be a lack of motivation. Noreen Webb (1982) referred to a study which indicated that passive behaviour was not conducive to learning and Kempa and Ayob (1991) elaborated further on this. They considered that if the passivity was self imposed and the student did participate

sometimes, they had opportunities to learn. However, if it was imposed by the group through their attitudes or actions, the student was less likely to learn.

Assertion 7/63

Individual group members, either male or female, may use the equipment to the exclusion or partial exclusion of others.

Assertion 7/64

The students with less knowledge in a mixed ability group may not participate as effectively in activities and discussions as those with more knowledge.

During the group activity time, most of the group interactions were related to managing the task and equipment as suggested in Assertion 6/45 (Most group work interactions relate to management). The exception was Mr Carter's group, where most of the interactions were social.

The level of 'on-taskness' was difficult to judge in Mr Avery's and Ms Brown's groups with students sometimes engaging in social conversation, although still supporting the other members who were constructing circuits. At other times, when the attention seemed similar they were less aware of what had been happening. During the group work, awareness of off-task group members varied. In Mr Avery's group, usually all the members were attentive but there were a few overt reminders when necessary. In Ms Brown's group there were only limited attempts to ensure others were attending. The Focus Group students from Mr Carter's class often ignored any attempts to involve them in activities and found it very difficult to stay on task, with the student constructing the circuits working in isolation with little or no support from other group members. Studies have indicated that, when students are on-task, they are more likely to learn (Ross, 1984) This does support Assertion 6/56 (Students need skills to work collaboratively and solve problems in groups) but also introduces two new Assertions.

Assertion 7/65

Students in groups need to ensure that all members are involved in the task.

Assertion 7/66

The students' level of attention during group work may affect their opportunities to learn.

Myers (1990) indicated that ensuring students were on-task was an important job of the teacher and studies have demonstrated that students are generally not as involved in the work when a teacher is not at the group (Anderson, 1984; Berliner & Rosenshine, 1977; Croll & Moses, 1988). The teachers in the study generally did not visit the Focus Groups very often, with the students generally on-task when the teacher was there. Mr Avery's group maintained their attention levels at an acceptable level when the teacher was not attending, as did Ms Brown's group most of the time, with much of their off-task behaviour occurring when they had completed the set work. Mr Carter's group were often only on-task when Mr Carter was at the group.

Assertion 7/67

The attendance of a teacher at a group improves group attentiveness.

Assertion 7/68

Groups need to be taught strategies to enhance attentiveness.

Linn and Burbules (1993) and Pintrich et al. (1993) suggested that students may be more concerned with social goals than academic. The Focus Group from Mr Avery's class demonstrated the best work habits, with not only little distracting social conversation, but also mostly positive interactions. The Focus Group from Ms Brown's class was less focussed with two group members engaging in frequent social conversation and another group member whose participation was limited. Mr Carter's Focus Group were the least able to work and discuss constructively. There was a considerable amount of social conversation, which was often negative and derogatory but in which all the students participated.

When examining task completion, Mr Avery's group was far more successful at completing tasks than either of the other groups, with Mr Carter's group often leaving tasks incomplete or allowing one student to do the work whilst the others engaged in irrelevant conversation. Ms Brown's group completed most given tasks, but was less successful when Neil was absent and the group dynamics were less positive. If practical tasks are not completed, the students would be less likely to understand subsequent discussion, and this would limit the development of understandings. Ross (1984) considered that on-task behaviour was important as it increased the amount of learning.

Assertion 7/69

The social dynamics of the group may affect their on-task behaviours.

Assertion 7/70

Groups which infrequently engage in extended social conversation demonstrate more success in completing tasks.

Assertion 7/71

Groups which engage in positive interactions demonstrate more success in completing tasks.

Assertion 7/72

Students who do not complete practical activities may find it more difficult to develop understandings.

Discussion is an important aspect of social constructivist learning (Cosgrove & Osborne, 1985a, 1985b; Driver & Scott, 1986). Group discussion in both Mr Avery's and Ms Brown's class was generally positive and constructive and any negative comments, of which there were fewer in Mr Avery's class, were usually friendly. Both Mr Avery's and Ms Brown's groups engaged in discussion when requested, with Mr Avery's group more able to work through understandings and reach consensus than Ms Brown's. However, both groups were able to discuss reasonably effectively, a skill which Linn and Burbules (1993) felt many students did not have. Mr Carter's group often did not discuss when requested and showed little evidence of constructive discussion, with constant negative comments.

Assertion 7/73

Friendly interactions and effective discussion skills provide more opportunities for learning and therefore better construction of understandings.

Generally both Mr Avery's and Ms Brown's groups allowed all students the opportunity to speak during discussions, although Ms Brown's group was less fair when Neil was away. Most of the students joined in, although, as with the activities, the lower scoring students were less likely to participate, corroborating Noreen Webb's (1982, 1985) findings. In Mr Carter's group, the negative comments during discussions limited reasonable discussion, and precluded reasonable turn-taking or explanations. Mr Avery's and Ms Brown's students usually responded to questions from group members, with students sometimes explaining how an answer was reached. Studies indicate that

explanatory answers offer opportunities for learning for both the explainer and the questioner (Wehh, N., 1982, 1985).

Assertion 7/74

Students who engage in cooperative discussion give all students in the group opportunities to develop understandings.

Assertion 7/75

Answers which include explanations allow more opportunity for discussion and learning.

Brown and Palnscar (1989) and Tao and Gunstone (1997) discussed the benefits of articulation and co-construction of understandings. The Focus Group from Mr Avery's class demonstrated an ability to build on each other's understandings, as did Ms Brown's group, although it occurred less often in this group and sometimes produced non-scientific understandings (Linn & Burbules, 1993; Solomon, 1989). Mr Carter's group showed no real evidence of this skill. Mr Avery's group often discussed topics which were not specifically requested by Mr Avery and also engaged in student initiated discussion. Ms Brown's group only engaged in limited discussions outside those requested and these were sometimes inconclusive. Mr Carter's Focus Group did not engage in any science discussion other than that requested by Mr Carter

Assertion 7/76

Students who are able to accept and build on comments from others have more opportunities to develop understandings.

Assertion 7/77

Students who engage in incidental discussion during activities as well as in the discussions suggested by the teacher have more opportunities to develop understandings.

In all the groups the interactions were mainly very short with only a few being more than 10 words, although when the teachers were present there was more evidence of longer statements, although less so in Ms Brown's class.

Assertion 7/78

Group discussion in primary schools is often only made up of short statements.

Generally the teachers did not pay particular attention to the Focus Groups, although both Mr Avery and Mr Carter on occasion spent some time with them. Mr Avery and Ms Brown only facilitated understandings with the Focus Groups in a limited fashion (Driver, 1989; Webb, N., 1985) but, when Mr Carter visited the Focus Group, his facilitation of discussion was effective and produced the only constructive discussions from the group. This supports Assertion 6/51 (Teacher visits to groups help students develop understandings), but also introduces Assertion 7/80

Assertion 7/79

Teacher support enables more constructive discussions to occur.

Discussion in science lessons should help the students to develop understandings (Barnes, 1976; Thomson, 1978) and Lemke (1990) suggested that knowledge of the appropriate language gives the students an opportunity to discuss using scientific terms. The use of scientific language in all the Focus Groups during the group discussions was limited, with that in Mr Carter's group being very limited. The level of explanation of scientific terms varied, with Mr Avery's group demonstrating the best understanding. All the teachers only used a limited range of scientific terms when engaged with the groups. The students' use and understanding of scientific terms may reflect the level of explanation offered by the teachers as Mr Avery explained more of the scientific terms than any other teacher, and used them reasonably consistently; Ms Brown only used a limited range of terms, only explaining some of them; and Mr Carter explained some of the terms he used, but his use of scientific language was more limited than Mr Avery and he used very few scientific terms when talking to the group. Many studies have examined the understanding students have of scientific terms (eg. Bell & Freyberg, 1985; Osborne et al., 1983) and have indicated that, where terms are not understood by students, the understandings that they develop are likely to be incorrect. These comments support Assertions 5/18 and 5/19 (Teachers' use and explanation of science terms) and 5/42 (Students use few scientific terms).

Mr Avery's group was able to follow the instructions, either those given verbally or those on the worksheets, and was confident enough to continue on with the task if no instructions had been given. The group from Ms Brown's class waited for instructions rather than follow the worksheets and much of their off-task behaviour occurred during

the times they were waiting. Mr Carter's group only followed any instructions in a limited fashion and did not attempt to progress further. Mr Avery's class were allowed to work independently and appeared to be allowed more responsibility than the other classes. These attributes carried over into their group work.

Assertion 7/80

Students who are used to working independently of the teacher maintain this when working in groups.

All the groups had some opportunities to discuss work related to the Summary Sheets or the Summary Sheet problems prior to completing them. The discussion was often constructive and useful although Mr Carter's Focus Group did not use the questions effectively and their discussion remained limited. The Summary Sheets and the focus questions provided a structure for the groups' discussions and, even when they were not used effectively as with Mr Carter's group, did provide questions that needed responses.

Assertion 7/81

A framework for discussion, eg, a list of questions which need responses, encourages all the students to respond in a discussion. However, it may not necessarily result in good discussion.

Part of the groups' work was to listen and pay attention during whole-class discussions. The differences between the quality of the various discussions has already been discussed in Chapter 5 and these differences would affect the attention of the students. However, within the groups differences occurred. All groups were off-task at times during the whole-class discussions, with the group from Mr Avery's class most likely to be attentive although they all appeared off-task on occasion. However, it was difficult to ascertain their level of attention as, even when they were doing something else, they still responded to Mr Avery's questions. Only one member of Ms Brown's Focus Group paid good attention during discussions with the others often off-task. The Focus Group from Mr Carter's class were frequently off-task. Generally, the boys were more likely to be off-task than the girls. These comments support Assertion 5/7 (Student attention is improved when materials are not available) but also introduce Assertion 7/82.

Assertion 7/82

Even when students appear inattentive during whole-class discussions they may still be paying attention.

Summary

When the Focus Group behaviours are examined, it is apparent that all the groups engaged in some behaviours that were not conducive to learning, although Mr Avery's group showed more positive behaviours than the other two (Figure 7.7).

Mr Avery's students	Ms Brown's students	Mr Carter's students
All high ability students	More able students	Mostly able students
Some knowledge of electric circuits within the group which was shared with group members	One member knowledgeable about electric circuits who shared his knowledge with the group	Some knowledge of electric circuits but rarely offered to group members
Cohesive group	Reasonably cohesive group	Very uncohesive group
Emergence of a leader who was accepted by other group members. More than one student able to take role of leader	One member tended to lead in discussions and activities but one other student partially took on leader's role when needed	No overt leader in group
One student participated less in activities and discussion	One student participated less in activities and discussion	One student participated less in activities and discussion
Most group interactions were managing the task	Most group interactions were managing the task	Most group interactions were social
Attempts to ensure all students were attending during activities and discussions	Limited attempts to ensure all students were attending during activities and discussions	Some attempts to ensure all students were attending during activities and discussions but ignored by group
All students usually involved in the activity	All students sometimes involved with the activity	Apart from the first lesson, limited participation and construction by most members
Discussion and support in circuit building	Discussion and support in circuit building	Rarely any discussion or support during circuit building
Limited off task behaviour and social conversation	Some off task behaviour and social conversation mostly by the same two group members	Frequently off-task with much of the time taken up with social conversation
Interactions usually positive	Interactions mostly positive	Interactions often negative
All students completed most written and activity work both set by the teacher and on the worksheets	Some students completed most written work when set by the teacher. Most activity work completed	Some members unwilling to complete written work. Little group effort put into completing activities
Usually discussed when asked to by teacher	Limited discussion requested by teacher. Did discuss when asked	Rarely discussed in any detail when requested
Democratic as far as turn taking and discussions concerned.	Sometimes shared tasks and discussions fairly	No evidence of fair distribution of any tasks
Able to discuss in a group and reach a decision	Able to discuss in a group but unable to reach decisions	Unable to discuss constructively in a group
Some conceptual discussion and able to build on ideas of other students	Limited conceptual discussion and occasionally built on each others ideas	Minimal conceptual discussion and did not build understandings cooperatively
All students participated in discussions although at different levels	All students participated in discussions although at different levels	Limited participation in discussions

Mr Avery's students	Ms Brown's students	Mr Carter's students
Responded to and discussed questions on worksheets with some group discussion instigated by group members	Limited discussion of worksheet questions unless requested by Ms Brown. Little discussion instigated by group.	No discussion of worksheet questions and only limited discussion when requested by teacher
Most interactions in group fairly short with a few longer statements	Most interactions in group fairly short with a few longer statements	Most interactions in group fairly short with a few longer statements
Teacher attended group occasionally and engaged in conceptual discussion	Teacher rarely attended group and engaged in little conceptual discussion	Teacher attended group on two occasions and engaged in constructive conceptual discussion
Used some scientific terms	Very little use of scientific terms	Rarely used scientific terms
Understood the meaning of some science terms	Understood the meaning of some science terms	Understood the meaning of some science terms
Willingness to follow instructions and continue with task without further instructions	Followed instructions but would not continue task independently resulting in off-task behaviour	Sometimes followed instructions and made no attempt to continue task without instructions
Good discussion when given focus questions	Group members not given focus questions	Usually poor discussion when given focus questions
Discussion of Summary Sheets	Discussion and group work on Summary Sheets	Limited responses to questions related to Summary Sheets
Attention paid during whole class discussions, although students sometimes off-task, usually appeared to be listening	Limited attention during whole class discussions	Limited attention during whole class discussions



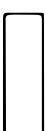
 Situations that increased opportunities for learning	 Situations that limited opportunities for learning	 Situations that inhibited opportunities for learning
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Figure 7.7. Focus groups: Opportunities for learning

The Focus Group from Mr Avery's class were the most cooperative and productive workers, with Ms Brown's Focus Group providing some opportunities for the development of understanding. The group from Mr Carter's class engaged in few behaviours that promoted opportunities for learning. The teachers attendance at the groups also varied with Mr Avery engaging in some constructive discussion; Ms Brown rarely contributing to the group discussion; and Mr Carter managing the group discussion so that understandings were developed.

The next chapter compares two teachers' methods of developing understandings for Proposition 5, electric current travels in one direction through a circuit and then compares Mr Avery's development of Proposition 2, the amount of current in any part of a circuit is the same, and Proposition 3, the position of joins in a circuit.

CHAPTER 8

How the Propositions Were Taught: A Comparison of Teaching Methods

Overview

The discussions in Chapters 5 - 7 have taken a broad look at the three teachers' methods of teaching throughout the series of lessons, and have demonstrated the differences in their classroom practice, as well as describing the students' behaviours and attitudes. However, the teaching and learning that occurred for individual propositions has not been discussed. Students' opportunities for learning for specific propositions varied between teachers, and it was also apparent that, in some cases, teachers offered better learning opportunities for some propositions than for others. This Chapter examines two teaching situations. The first compares Mr Avery's and Ms Brown's teaching of Proposition 5, the direction of current flow; the second compares Mr Avery's teaching of Proposition 2, the amount of current in any part of a circuit is the same, and Proposition 3, the points at which a circuit must be connected.

This Chapter describes the teaching that occurred and the understandings of these particular propositions that were developed by the classes. The discussion summarises the differences in learning opportunities that occurred and generates further assertions. Chapter 9 describes the conceptual changes that occurred in the three classes for all the propositions.

Mr Avery's and Ms Brown's Teaching of Proposition 5: Electric Current Travels in One Direction Through a Circuit.

A variety of learning experiences were available to provide opportunities for improving students' conceptions of current flow in a circuit. In Lesson 1 the group work involved discussing the direction of current flow and the focus questions for the end of lesson discussion also addressed this concept. The drama activity, which involved students in role-playing the components in a simple electric circuit and the ammeter demonstration were designed to demonstrate that the electric current did not get consumed in the globe. Both of these could also have been used to consider direction of current flow. Although Mr Avery and Ms Brown taught the initial lesson for similar periods of time, Mr Avery's lesson was spread over two days.

Mr Avery's Teaching

Lesson 1a

Mr Avery discussed or reinforced this concept in most lessons (Figure 8.1). During Lesson 1, after the students had constructed the first simple circuits using only one wire, a battery and a globe, and had completed some recording, he asked the students in their groups to discuss the direction of current flow. Two minutes was allowed for this although not all groups followed the instructions. Mr Avery circulated round the class, visited one group and asked for their ideas. There was some discussion between the students as to whether the current flow was negative to positive or positive to negative with students explaining their reasoning although Mr Avery avoided evaluating their discussion. As not all students were discussing the question Mr Avery repeated his instructions although, as indicated by the Focus Group data, some groups still did not engage in the requested discussion.

When the whole-class discussion started, Sue and Jon from the Focus Group were involved in a brief discussion to which all the students in the group listened, where Jon stated that the current flowed from positive to negative. In the ensuing whole-class discussion Mr Avery initially explained how to identify the positive and negative terminals of a battery and then allowed a variety of ideas of current flow to be submitted, but did not evaluate these or indicate which answer was correct. Bob, from the Focus Group, was one of the respondents. When asked the direction of current flow by Mr Avery, he stated that it flowed from negative to positive. Jon, within the group, responded negatively and raised his hand to offer his idea, which was then suggested by a different student. All the students were involved in this discussion, with many students wanting to respond. The students then constructed and recorded circuits made with two wires, a battery and a globe. Later, when the class was deciding whether a selection of these circuits drawn on the blackboard by students would work or not, Mr Avery suggested that the fact that a circuit with both connections to the top of the battery would not work was proof that one student's idea of a hi-polar view of current flow was invalid, however he did not elaborate on this.

The use of galvanometers instead of ammeters in the demonstration in Lesson 1a would have made it easier to demonstrate the direction of current flow. Mr Avery did use the ammeters in this way although in a limited fashion. He did not call the students out to the front of the class to watch the demonstration but circulated round the groups showing all the students the circuit and asked a student to help in the demonstration. He

demonstrated the flow of current with the battery correctly attached and then asked the students to predict what would happen if the battery was reversed. Although initially there was one dissenting voice the consensus was that the circuit would not work. He then demonstrated that the globe still lit and asked students to suggest what was happening. He repeated the demonstration until a student suggested the current was flowing backwards, which was positively evaluated. The fact that the current flowed from negative to positive was not emphasised during the demonstration although it was presented after the demonstration, incidentally, in a long explanation:

Mr Avery Now let's look at the importance of the flow of electricity. This is what's been happening. We said earlier on, when we connected it up that, it was actually Bob who said it, that it flowed from the negative to there and got used and then we used some of the energy and it came back this way. As soon as I flipped it (the battery) over we still had energy going through but it went in a different direction. As soon as I turned my battery around I get the electrons going in a different direction and that's what that showed. (Lesson 1a)

This was the first time that Mr Avery had stated that current flowed in a circuit from negative to positive and there was no reaction from the students.

Whilst the groups were discussing and producing answers to the focus questions, Mr Avery circulated round the class ensuring the students were on-task and helping the groups where necessary. When the Focus Group discussed the focus questions, Jon dominated the discussion of the question referring to the direction of current flow, strongly emphasising that current flowed positive to negative.

After the materials had been packed away and the students were turned to face Mr Avery, he conducted an end of lesson discussion based on the focus questions. During this discussion, Jon, from the Focus Group, who felt that current flowed from positive to negative, stated that Mr Avery had agreed that this was correct earlier in the lesson. In fact Mr Avery had accepted all the suggestions offered by the students and had not positively evaluated any of them. However, he had used the negative to positive current flow concept in the explanation described. There was an interchange of views between Mr Avery and the students with Mr Avery emphasising very strongly that the current flow was from negative to positive:

Mr Avery Let's go to the next one. Where do you think the electrical current was travelling to and from, electrical current was flowing to and from? Jon.
Jon It's running from positive to negative.
Mr Avery Positive to negative? Is that what we said? No.

Student *It's coming from the positive * negative.*
Mr Avery *Negative, it's going from the negative.*
Student *No, you told us that didn't work before when we suggested it.*
Mr Avery *No, I agreed with what Bob said.*
Bob *Far out.*
Student *Yes, because it has to flow that way because *** other way but it really meant to flow negative to positive.*
Mr Avery *Negative to positive, that 's how it goes.*
Student *You told us that was wrong!"*
Mr Avery *No, I didn't say, no way did I say*
Student *You did!*
Mr Avery *say that. (Lesson 1a)*

It was noticeable during this lesson that the students were interested, not only in the activities but also in the discussion, and the dissension just described held the whole class's interest, particularly that of the Focus Group.

Lesson 1b

The follow-up discussion and writing lesson (Lesson 1b) allowed Mr Avery to emphasise the concept of negative to positive flow, on the first occasion using the supplied diagram of a simple circuit (Appendix 3), however he did not complete his explanation:

Mr Avery *With electricity, in order for the globe to light up, this globe here (following circuit diagram) to light up, we need to have the electrons flowing from a battery, which is the power source, flowing through the wire in, and the casing on the outside of the globe allows the electricity or the electrons to be conducted through and it goes up into this little filament. (Lesson 1b)*

He then discussed other aspects of electric circuits and, shortly afterwards, described a complete circuit, again using the diagram.

He then showed a circuit which included ammeters, although it was not fully connected, and asked the students how the current would flow. The student who responded said that it flowed anti-clockwise as it did in that particular situation and, although Mr Avery accepted the answer he also demonstrated the direction of current flow with his finger. After some further discussion he again described the direction of current flow and demonstrated it on the diagram. The students then copied the diagram from the poster and two statements from the blackboard:

Electricity is the flow of electrons.

A circuit is a circle.

Most students included the arrows showing the direction of current flow and, whilst the students were working on this, Mr Avery circulated and helped.

The role-play, which was also part of this lesson, did not indicate that the flow of current was from negative to positive but did show that current flows in a circuit, and Mr Avery's use and explanation of the term 'electrons' instead of electric current in Lessons 1a and 1b would have helped the students relate the electrons in the role-play to the electric circuit. As Mr Avery talked the students through the activity he guided them in a circle through the circuit, again emphasising the circular flow of electric current.

After the students completed the Summary Sheets he asked some students to draw their answers on the blackboard. He again showed the students the direction of current flow twice on one diagram.

The students appeared less on task in this lesson, with some students working on their topic title pages during the initial discussion, and a few students not completing their written work. However, most students were paying attention during the demonstrations and the role-play, and were on-task during the Summary Sheet work.

The remaining lessons

Towards the end of Lesson 2 Mr Avery again demonstrated the direction of current flow on the supplied diagram:

Mr Avery Okey what we did today was again continue that idea of the circuit as we have over here. The battery from the negative we have it going through the casing through the filament which uses the energy to light up the globe than back out through the bottom tip of the globe right through back to the battery'. (Lesson 2)

At the beginning of Lesson 3, when Mr Avery was reviewing the previous week's work, he again used a diagram to demonstrate current flow and described it fully. During this and all of the following lessons the correct understanding of current flow through a circuit was either stated or indicated by tracing circuits on diagrams from negative to positive. On one occasion he started tracing the current flow incorrectly but immediately corrected himself and changed direction.

Summary of Teaching

When examining the transcripts it is apparent that Mr Avery frequently addressed this concept and the relevant information was constantly referred to, either directly or indirectly, and the students had many opportunities to develop scientific understandings (Figure 8.1).

Lesson/ Record	Activity type	Participants	Activity or discussion details
1a	Group activity	SS	Constructed and recorded circuits with one wire, a battery and a globe
1a	Group discussion	SS I	The direction of current flow and where it is found in the circuit Circulated and discussed ideas with groups
1a FG291 1a	Focus Group Whole-class discussion	Pat I	Attempted to start discussion on direction of current flow Repeated instructions to discuss direction of current flow Discussed what electric current was
1a	Group discussion	SS I	The direction of current flow and where it is found in the circuit Circulated and talked to one group about current flow
1a	Focus Group		Did not discuss current flow
1a	Whole-class discussion		Direction of current flow
1a FG315-320	Focus Group		Brief discussion at start of whole class discussion where Jon stated current flow was positive to negative
1a 1a 248-249 1a 265-267 1a 269-270 1a 272-279	Whole-class discussion	SS SS SS SS T	Direction of current flow <ul style="list-style-type: none"> From the battery to the globe Negative to positive From both ends of the battery to the globe Positive to negative No evaluation
1a 280-289 1a 301		SS T	Identified working and non-working circuits drawn on blackboard Used finger to trace flow of current round a circuit
1a 1a	Group activity	SS SS	Constructed simple circuits with two wires, a battery and a globe Drew working and non-working circuits on blackboard
1a 494-531	Whole-class discussion	SS	Identified working and non-working circuits drawn on blackboard
1a 494-531		SS T	Corrected blackboard diagrams by changing position of joins <ul style="list-style-type: none"> Suggested that a circuit that did not work was evidence that a bi-polar view of current flow would not work
1a 538-621 1a 554&572 1a 557-603 1a 604, 607, 612, & 614 1a 605 1a 610, 611, & 620 1a 616 1a 621 1a 625 1a 626	Ammeter demonstration	T T T SS SS SS SS T T T	Discussed current flow within the circuit The current in both sides of the circuit is the same (stated twice) Reversed battery in ammeter circuit, showed change in alignment of needle and asked what had happened <ul style="list-style-type: none"> Current is flowing the wrong way <ul style="list-style-type: none"> The flow has stopped The current is flowing backwards <ul style="list-style-type: none"> It's flowing a different way It was flowing backwards Current flows from negative to positive When the battery is reversed the electrons are going in a different direction The flow of current is the flow of electrons
1a	Activity	SS T	Students in groups worked together on question sheets Discussed current flow with one student
1a FG570-582, 605-619	Focus Group		Jon dominated direction of flow discussion stating it flowed from positive to negative
1a 717 1a 718 1a 719-731 1a 722 & 728 1a 732-735 1a 749	Whole-class discussion	S T T T T	Discussed question sheets - direction of current flow <ul style="list-style-type: none"> Positive to negative Negative to positive - class discussion Current flows negative to positive (repeated) Current flows negative to positive as shown by the ammeter demonstration Electric current flows in a circle Followed circuit on blackboard diagram
1b 9 1b 22 1b 32	Whole-class review	T T T	<ul style="list-style-type: none"> Electricity is the flow of electrons Followed and described current flow on circuit diagram (not completed) Followed and described current flow on circuit diagram stating the flow was from negative through the circuit

Lesson/ Record	Activity type	Participants	Activity or discussion details
1b 38		T	Used ammeter circuit (not working) to ask which way flow would be
1b 41-43		S	• <i>Anti-clockwise</i> (negative to positive)
		T	Positively evaluated and followed and described current flow on ammeter circuit
1b 61		T	Followed current flow on circuit diagram stating the flow was from negative through the circuit
1b	Group work	SS	Copied statements from blackboard and drew simple circuit with directional arrows on it
1b	Focus Group		Completed activity with no conceptual discussion
1b 93-141	Role-play	T	Instructions directed students to move in a circle indicating electrons flowed round a circuit in one direction
1b	Group work	SS	Summary sheet discussion, no current flow concepts
1b 222	Summary sheet	S	Drew possible answer on blackboard
1b 231		T	Followed two current flow possibilities on student diagram
2	Activity	SS	Simple circuit, testing conductors
2 921	Whole-class discussion	T	Followed current flow on circuit diagram stating the flow was from negative through the circuit
3 16	Whole-class review	T	Followed and described current flow on diagram
3	Activity	SS	Batteries in series
3 524 & 526	Whole-class discussion	T	Followed and described circuit flow through two series circuit diagrams on blackboard
3 811	Whole-class discussion	T	Followed and described circuit flow on torch poster
3/4	Activity	SS	Globes in series and parallel
3/4 453	Whole-class discussion	T	Followed and described circuit flow on blackboard diagram
3/4 653	Whole-class discussion	T	Electrons flow from the negative
3/4 684		T	Followed circuit flow on blackboard diagram
3/4 685-692		T	Used bridge analogy, followed circuit flow on blackboard diagrams of series and parallel circuits
3/4 706		T	Followed and described circuit flow on student's blackboard diagram partially using bridge analogy
3/4b 50	Whole-class review	T	Followed circuit flow on poster
4	Activity	SS	Batteries in parallel
4 585	Whole-class discussion	T	Followed circuit flow on diagram on blackboard

Note: • Indicates explanation generated or offered

Participants: T - Mr Avery, S - Individual student, SS - Several students.

T/SS - Mr Avery and one or more students

<input type="checkbox"/>	Concept discussed or demonstrated	<input type="checkbox"/>	Concept implied	<input type="checkbox"/>	Concept not discussed or incorrect statements
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Figure 8.1. Summary of activities and interactions which provided opportunities for developing understanding of Proposition 5.

Changes in Students' Understandings

On the pretest, no student demonstrated an acceptable understanding of current flow in a circuit, ie. a circuit view with current flow from negative to positive. In the posttest 13 students, 52% of the class, demonstrated an acceptable understanding, with a further

seven selecting a positive to negative flow of current indicating that, in total, 80% of the students had adopted a circuit view of current flow (Table 8.1).

Table 8.1

Type and Number of Student Responses to Question 9 from Mr Avery's Class on the Pre and Posttests (n = 25)

Type of response	Number of responses	
	Pretest	Posttest
Correct	0	13
Positive to negative flow	7	7
Bi-polar	13	2
Uni-polar	1	1
Invalid answer	0	1
No response	4	1

The 13 students with correct answers in the posttest all demonstrated some understanding in their explanations although they varied in quality:

IM25 *Because the current is flowing in a circuit from negative to positive.*

IF19 *Because negative goes to positive.*

Of the seven students with a positive to negative view, three did not offer explanations, one gave an explanation which included the idea of a circuit and the remaining students' explanations were limited:

IF5 *The current goes from positive to negative.*

IF26 *It goes out the positive and in the negative.*

Two students, who made no response on the pretest, demonstrated a bi-polar view and one maintained her uni-polar view. Pat, from the Focus Group, showed a negative to positive flow on her diagram but her explanation stated the opposite:

Pat *Because it is flowing in a circuit from positive to negative. (Posttest)*

Pat may have been considering current flow through the battery and not the whole circuit as, when asked in the interview, she indicated the flow of the current through the battery and not through the circuit.

Jon changed to the correct understanding between the pre and posttest, indicating that the nature of the discussion had made an impression on him. He changed few of his understandings between the two tests.

Ms Brown's Teaching

Lesson 1

Although this proposition was mentioned in most lessons it was only rarely clearly defined (Figure 8.3). After the students had completed the initial activity in Lesson 1, constructing and recording circuits built using one wire, a globe and a battery and identifying working circuits. Ms Brown suggested the groups discuss the direction of current flow:

Ms Brown Perhaps it would be a good idea now to see if you can work out how the electric current worked from your battery and how the electric current worked through the circuit, and see if you can work out which direction you think the electric current might have been moving in. (Lesson 1)

Most of the groups had some discussion although in many groups there were still students using the equipment. Ms Brown circulated and asked three groups to put arrows on the diagrams showing the direction of current flow. She visited two groups to discuss this concept, with student responses initially indicating a bi-polar view of current flow. An attempt to redirect the students' ideas in the first group did not appear to be successful:

Ms Brown Which way do you think the electric current was moving?
Student Um, they all head for to join together and light up.
Ms Brown Alright. So where does the current move from. It moves from the base around there, through the globe and what happens to it once it gets to the globe?
Student It glows.
Student It joins together.
Ms Brown All right then. Is that, is that where the electric current stops is it?
Student Uh, Yeah
Ms Brown Okay, well if the electric current stopped at the globe would you have to have the globe sitting on top of the battery for it to work. Try that.
Student It doesn't work.
Student Because, um, they they're attracted to each other. Different energy it must be and they head for each other through * (Lesson 1, group interaction)

A student in this group then made a statement indicating that she felt that the current flowed in a circle with Ms Brown making a neutral response and then leaving the group:

Ms Brown You think it goes round through. All right then, draw an arrow on your diagram to show what you are doing. (Lesson 1, group interaction)

The second group that Ms Brown talked to also had a bi-polar view and again one student possibly had a correct understanding but the discussion was ended by Ms Brown

when she started the whole-class discussion after just over three minutes of group discussion.

The discussion in the Focus Group was inconclusive (p. 173). The group felt that the current travelled from positive to negative although Katy recognised their lack of knowledge when she said, "We only think it goes out the positive and in the negative". Ryan suggested that the current went clockwise but Neil's response and demonstration with a circuit showed that he had realised that the way the circuit was observed would change the direction of flow from clockwise to anti-clockwise.

As the only circuits that had been completed were those using only one piece of wire, the current flow was through the globe directly to the positive terminal of the battery. In the whole-class discussion Ms Brown questioned Neil, one of the Focus Group students who had some knowledge of electric circuits, with no recognition that other students may have different views of current flow:

- Ms Brown* *Okay. A lot of you have managed to draw some arrows on your diagram but when you got to the globe what happened to the current? It made, what did it do? What happened to the current then? Neil?*
- Neil* *It got less.*
- Ms Brown* *It got er, some people are talking. I can't hear you.*
- Neil* *It got less.*
- Ms Brown* *That's a warning. (To student talking)*
- Neil* *It got weaker.*
- Ms Brown* *Pardon?*
- Neil* *It got weaker.*
- Ms Brown* *The current became weaker. What happened to the rest of the current then that was left?*
- Neil* *It kept on moving.*
- Ms Brown* *Moving where?*
- Neil* *In a sort of circle.*
- Ms Brown* *In a circuit through what?*
- Neil* *Through the wire.*
- Ms Brown* *I can't hear you.*
- Neil* *It just kept going through the wire.*
- Ms Brown* *So you said the current kept going through the wire. But you explained that the current came from the wire into the globe. Where did it go once it reached the globe?*
- Neil* *Through the battery.*
- Ms Brown* *Through the battery. Okay. All right then. (Lesson 1)*

Neil, initially, did not say where the current was coming from and, from the ensuing conversation, it appears that Ms Brown assumed that he was referring to the current coming from the wire. However, when the Focus Group discussion is analysed (p. 173), it was apparent that Neil, although he was aware that current moves in a circle, had a

positive to negative view of current flow, and would have assumed that the current was coming from the top of the battery. When Ms Brown stated that the current was coming from the wire into the globe, Neil changed his view and said that the current travelled through the battery after travelling through the globe indicating a negative to positive view of current flow. Although this segment does indicate a negative to positive view of current flow, because of the many questions it is difficult to follow and was not summarised at the end by the teacher, which might have made it clearer to the listeners. However, as indicated by Ms Brown's control comments, the students in the class were generally inattentive with some using the equipment and others talking.

The students then constructed circuits with two wires, one battery and one globe and, during this time, Ms Brown circulated round the groups asking them to label the positive and negative terminals of the batteries, stopping the whole class to explain how to identify them. She did not evaluate any of the directional arrows that students had put on their diagrams and the work was not marked later. Only six students actually added their arrows correctly, 10 added them incorrectly and the remainder did not use arrows. In the Focus group, Katy and Ryan both drew their arrows from positive to negative and Neil and Tina from negative to positive.

One student constructed and then drew on the blackboard a non-working circuit where the battery was connected with a wire from the negative to the positive terminals and a second wire leading from the positive terminal to the globe which was not connected to the battery in any other way. The ensuing discussion was unclear and a summary at the end would have made it easier to understand:

- Ms Brown* *Why didn't it work? Does anybody have any idea why it didn't work?*
Paul.
- Paul* *Because the battery needs to be hooked up to the positive and negative, um, in that diagram it's only hooked up the positive.*
- Ms Brown* *Now, have you explained it properly? You've said the battery needs to be hooked up to the positive and negative. Well, we've got a wire.*
- Lucy* *But where it's touching the positive it's got plastic on it. So electricity won't go through*
- Ms Brown* *Does that explain fully? Who can give a add to the explanation that um Lucy and er Paul have given? Why that one didn't work? Think of it in terms of a circuit. Yes, Eric.*
- Eric* *The circuit went from er negative to positive and stopped there. It went straight into the battery instead of carrying on*
- Ms Brown* *Right, so you're saying the circuit went round here and into the battery and (Following wire from negative to positive)*
- Eric* *Didn't go round.*

Ms Brown Didn't go round So you feel the circuit is definitely going from negative to positive and through the battery and this part didn't connect up. (Referring to the wire with the globe) All right, okay. (Lesson 1)

During the ammeter demonstration, designed to demonstrate that current flowed in a circuit and did not get used up in the globe, the students remained in their seats and it would be unlikely that they could either read the ammeters or see the way in which the battery was connected into the circuit. However, the students were generally attentive. In her explanation, Ms Brown did not discuss the direction of current flow and did not clearly explain that the current was flowing in a circle, with the emphasis being on the equal amount of current in the wires each side of the globe:

Ms Brown Okay, what we are looking at here. We have 200 amps of electricity coming through here and it goes through the globe and we have the same measure of electricity coming out of the globe as it goes through the circuit. (Indicating on ammeters) So, by doing this, what do you think we've discovered? That by the globe turning the light on, what have you noticed? Does it change the amount of electricity passing through?

Students Indecipherable murmurs

Ms Brown Does it use up electricity as it passes through?

Student Some saying yes, some no

Ms Brown Who thinks it does?

Seven students raise their hands, others looking round

Ms Brown Well have a look If it's got 200 just over 200 here and it's come out the other side and it's still registered as just over 200 Does it use up the electricity as it goes through?

Students No. (Lesson 1)

The pretest indicated that 14 students had a bi-polar view of circuit flow and some may have focussed on the ammeter readings and used this to support their theory. The student responses in this discussion were indecisive, but it is impossible to tell whether the indecisiveness related to the concept of electric current travelling in a circle or that of equal current flow through two wires.

The role-play activity demonstrated that electric current flows in a circle, although the direction of flow was not indicated. Ms Brown stated that electrons and electricity were the same when she was organising the students to take part:

Ms Brown Okay we're going to use some students who are going to be the electrons and this is the electricity. (Lesson 1)

Her explanation of the activity also indicated a circuit flow:

Ms Brown Okay, now what we're going to do is illustrate what happens with the electrons. As the electrons move through the battery they gather energy

and you're (student playing the battery) going to give each person a parcel of energy as they pass. Right, and they are going to carry that. The ammeter, Bill, all you have to do is count how many people pass, okay? Because you are counting the number of electrons which pass. But when you get to Eric, the electrons are going to pass some of the energy to Eric so that he has the energy. If he was really a globe he would light up. Okay? And the electrons then move in the circuit past Tony who is ... Past Tony who is also an ammeter and he's going to count the number of electrons who pass him. (Lesson 1)

Once again the students were attentive during this part of the lesson.

At the end of the lesson, four students drew working circuits on the blackboard. Ms Brown asked the first two to add arrows showing the direction of current flow. She helped the first student by explaining where the arrows needed to go, but the second student added them correctly. The third student did not put arrows on his diagram but Ms Brown demonstrated the direction of current flow using his diagram. During this session Ms Brown was constantly asking the students to pay attention and, in a period of four minutes, asked for attention 11 times.

During this lesson the students spent three periods of time totalling nearly 10 minutes waiting for selected students to draw circuits on the blackboard and often became off-task. The students' attention during the whole-class discussions was generally poor and, during the short segments of transcript recorded here, Ms Brown needed to gain attention four times, although in each case the interruption was fairly short. However, they did tend to fragment the explanations.

Lesson 2

During the review at the start of Lesson 2, one student described the role-play activity, indicating in his answer the idea of circuit flow:

Paul Electrons, that's it, and they pass um through the circuit and every time they pass through the battery they gain more energy, which they use to light the globe, um, and then sooner or later the battery runs out.
(Lesson 2)

Ms Brown then asked another student to repeat this and needed to question her to elicit each part of the information. There was no further teacher explanation of the concept and the direction of flow was not discussed.

After the students had constructed the circuits which included two wires joined by alligator clips, there was some discussion indicating that current flowed in a circle:

Ms Brown Take one of the alligator clips away.
Student It doesn't work.

Ms Brown *Right. Why doesn't it work? Emma.*
 Emma *Because it's not connected in a circle.*
 Ms Brown *All right then. So once you disconnect the two alligator clips, is there an electric circuit at all or is there an electric current flowing?*
 Students *No.*
 Ms Brown *Is there any electric current flowing? What makes the electric current flow? You have to do what? What makes the current flow? Yes, Joan.*
 Joan *Well, you have to connect them so that it's going round in a circle*
 Ms Brown *Right You have to have that circuit. (Lesson 2)*

Once again the class demonstrated their lack of attention with Ms Brown calling for whole-class attention twice and talking to a group of boys once during this segment.

Lesson 3

In Lesson 3 the students constructed series circuits. Once again the class spent a considerable amount of time watching students drawing circuits on the blackboard and became very inattentive. During this time Ms Brown described the circuits as joined negative to positive and in discussion talked about current flow:

Ms Brown *Okay. So you need to have that flow of current because how does the current flow? (referring to flow from battery terminals) How does it go? Sarah.*
 Student *Negative to positive.*
 Ms Brown *From negative to positive and it has to flow through. Okay. (Lesson 3)*

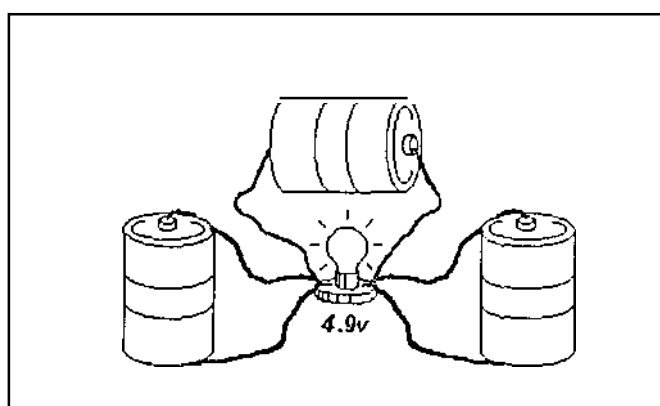


Figure 8.2. Circuit which did not make the globe brighter.

Later in the lesson when students were drawing circuits with three batteries on the blackboard, one student drew a circuit which did not make the light brighter because only one wire completed the circuit to the globe. Ms Brown, after questioning the class, explained why, pointing to the salient points on the diagram but not actually following the circuits (Figure 8.2):

Ms Brown *This is the only battery that's really got a complete circuit. The other ones are stopping here at this side. So the circuit is just running through the battery it's not going through the light. Can you see that? And the*

same is happening here. The circuit is coming from negative going right through, just through the battery but it's not actually going through the light. So that's why that's not working as well. (Lesson 3)

During the work with batteries in series in Lesson 3, Ms Brown frequently repeated the fact that batteries needed to be joined negative to positive without mentioning the direction of current flow, although on one occasion she referred to the connection as being positive to negative. The Focus Group discussion sometimes referred to the battery joins as being negative to positive and sometimes positive to negative. There was no mention of direction of current flow in Lessons 4a or 4b in either the whole-class discussion or the Focus Group discussion.

Summary of teaching

An analysis of the transcripts indicates that the discussion of current flow was often incidental and unclear, with the frequent interruptions because of inattentive students making the discussions difficult to follow. Many of Ms Brown's explanations were unclear or based on fragmented answers from students which were not then summarised by the teacher, and the concept was rarely clearly addressed during reviews (Figure 8.3). The poster with the simple circuit diagram with the direction of current flow marked on it was not referred to in any of the lessons.

Lesson/ Record	Activity type	Participants	Activity or discussion details
1	Group activity	SS	Constructed simple circuits with one wire, a battery and a globe
1 213-220	Whole-class discussion	W	Identified working and non-working circuits drawn on blackboard
1	Group discussion	T	The direction of current flow and where it is found in a circuit Involved in two groups discussions
1 FG202-253	Focus Group	All	Inconclusive discussion with consensus suggesting that current flow was positive to negative
1 294-297 1 298-301 1 302-304 1 305	Whole-class discussion	Neil Neil Neil T	<ul style="list-style-type: none"> • Current moved in a circle • Current kept going through the wire • Current went through the battery after it reached the globe • The current went through the battery
	Group activity	SS	Constructed simple circuits with two wires a battery and a globe
1	Whole-class discussion	T/SS	Discussed non-working circuit. • Circuit did not connect to globe (not clearly stated)
1 621-640	Ammeter demonstration	T	Demonstrated ammeter at the front of the class with students in their seats. Statement may have indicated current flowed in a circuit.
1 646-685	Role-play	T	Instructions directed student to move in a circle indicating electrons flowed round a circuit in one direction
	Group activity	SS	Constructed simple circuits with one wire, a battery and a globe
1 1 823 1 1 1	Whole-class discussion	SS T/SS T S S T	<p>Student drew working circuit on blackboard</p> <p>Ms Brown asked student to show direction of flow, showed it on the diagram and described. Student drew in arrows</p> <ul style="list-style-type: none"> • Current flows through the battery <p>Drew blackboard diagram and added directional arrows</p> <p>Drew blackboard diagram</p> <p>Followed and described current flow in circuit on blackboard diagram with her finger</p>

Lesson/ Record	Activity type	Participants	Activity or discussion details
2	Whole-class review	S	Electrons continually pass through the circuit and pick up energy (implied idea of circuit flow)
2	Group activity	SS	Constructed a simple circuit to test conductors using a globe holder and two wires in one side of the circuit
2 195-200	Whole-class discussion	T/SS	<ul style="list-style-type: none"> Components need to be connected in a circuit to make the current flow
3	Whole-class/ group activity	T	Gave step by step instructions to construct a simple circuit
3	Group activity	SS	Connected two batteries in series Recorded working and non-working circuits
3 FG285-286	Focus Group	Katy, Ryan & Tina	Series circuits need to have the batteries connected negative to positive
3 204(310) 3 3 310 3 314 3 315-319 3 320-322 3 323-325	Whole-class discussion	T S T T T/S T/S T/S	Instructed students to label positive and negative on the battery Three students drew working circuits on blackboard <ul style="list-style-type: none"> Described batteries as being joined negative to positive with a wire between Negative to positive circuits work If batteries are joined negative to negative it doesn't work If batteries are joined positive to positive it doesn't work Current has to flow negative to positive (referring to batteries in series circuits)
3	Group activity	SS	Connected three batteries in series
3 FG336-376	Focus Group	Katy, Ryan & Tina	Series circuits need to have the batteries connected negative to positive Series circuits need to have the batteries connected positive to negative
3 3 3 436-439 3 440 3 443 3 444-446 3 447 3 447 3 3 464	Whole-class discussion	SS S T S S T/S T T SS T	Two students drew working circuits on the blackboard Drew complex circuit using three batteries on the blackboard which only had a dim light Why didn't the globe go brighter? There were too many wires Would it help if the bottom battery was turned around? <ul style="list-style-type: none"> The top battery is providing the circuit Only one battery has a complete circuit The other circuits only allow the current to travel through the batteries not the light Two students drew working circuits on the blackboard <ul style="list-style-type: none"> Batteries needed to run in order positive to negative That is called a series circuit
	Group activity	SS	Constructed simple circuits using a 1.3V globe and one battery then added extra globes

Note: • Indicates explanation generated or offered

Participants: T - Ms Brown, S - Individual student, SS - Several students, T/SS - Ms Brown and one or more students



Concept discussed or demonstrated



Concept implied



Concept not discussed or incorrect statements

Figure 8.3. Summary of activities and interactions which provided opportunities for developing understanding of Proposition 5.

Changes in students' understandings

On the pretest one student demonstrated an acceptable understanding, but on the posttest, gave an explanation that did not agree with his diagram. In the posttest seven

students (22%), demonstrated an acceptable understanding, with a further 15 selecting a positive to negative flow of current indicating that, in total, 69% of the students had adopted a circuit view of current flow (Table 8.2). Three of the students who gave the correct responses on the posttest demonstrated a much improved level of understanding:

Pretest

2F40 The battery is the charger the source of electricity at the light bulb it is turned into light

Posttest

2F40 The globe just shows that electricity is passing through in a cycle picking up energy as it goes through the battery and giving it off at the globe

Table 8.2

Type and Number of Student Responses to Question 9 from Ms Brown's Class in Pre and Posttests (n = 32)

Type of response	Number of responses	
	Pretest	Posttest
Correct	1	7
Positive to negative flow	12	15
Bi-polar	15	6
Uni-polar	0	0
Invalid answer	0	4
No response	4	0

Katy from the Focus Group indicated a negative to positive flow in the posttest, however her explanation was unusual:

Katy The power starts at the globe and it passes through positive and the energy comes out negative towards the globe.

In the interview she made a similar statement and, when questioned, indicated that the circuit started in the wire leading from the globe to the positive terminal of the battery.

Of the 16 students with a positive to negative view, one offered no explanation

Four students included the idea of a circuit in their responses:

2M35 It will go like that because it comes out of the positive and travels round the circuit and goes in the negative.

Ryan, from the Focus Group, was one of these students and he considered in the pretest, posttest and interview that current travelled from positive to negative in a clockwise direction. The discussion previously described when Neil demonstrated that it

could not always he clockwise seemed to make little impression. Ryan’s view was queried in the interview with a circuit drawn with the globe on the opposite side and he was asked if it still travelled in a clockwise direction. He conceded that the direction depended on where the globe was but still felt it travelled from positive to negative. The remaining 11 students who chose positive to negative current flow gave low level explanations:

- 2M31

Positive goes to the globe and negative to the battery
- 2F51

The energy comes from the positive end

Four students retained their bi-polar view, and two changed from a positive to negative flow to bi-polar. Four students’ responses were recorded as invalid, with one of these choosing a negative to positive flow but explaining that the current flowed positive to negative and three giving explanations which were not able to be interpreted.

Comparison of Changes Between Classes

On the pretest, 28% of Mr Avery’s students had a circuit view of current flow with no students having a negative to positive view, and in Ms Brown’s class, 41% of students had a circuit view of current flow with one student (3%) holding the correct negative to positive view. After the series of lessons, the number of students with a circuit view of current flow in Mr Avery’s class (80%) had increased by 52%, and in Ms Brown’s class (69%) had increased by 28%. Mr Avery’s class also had a higher percentage of students who had learned the correct direction of current flow than Ms Brown’s class (Table 8.3).

Table 8.3
Changes in Students’ Understanding of Circuit Flow from Pre to Posttest

Circuit flow view	Mr Avery’s class			Ms Brown’s class		
	Pretest	Posttest	Change	Pretest	Posttest	Change
Negative>positive	0	13(52%)	13(52%)	1(3%)	7(22%)	6(19%)
Positive>negative	7(28%)	7(28%)	0	12(38%)	15(47%)	3(9%)
Total	7(28%)	20(80%)	13(52%)	13(41%)	22(69%)	9(28%)

The students in Mr Avery’s class also demonstrated more understanding of the concepts in their posttest explanations than those from Ms Brown’s class, with the mean score for Mr Avery’s students being 1.44 out of a possible score of four and that for Ms Brown’s students being 0.47.

Discussion

Many of the behaviours and strategies used by the two teachers have been discussed in previous chapters and the descriptions in this chapter have emphasised the differences in teaching that occurred. During the whole-class discussions the opportunities for learning offered by the two teachers were very different. Mr Avery's discussions moved quickly, flowed smoothly, were animated and included a variety of demonstrations and strategies, which resulted in students who were involved and attentive and who actively participated in the discussions and activities. Mr Avery's discussions covered more than was prescribed by the lesson outlines and his knowledge of the topic allowed him to restate the concept in a variety of ways and to respond to students' questions (Sanders et al. 1993; Wilson et al., 1987). Mr Avery constantly emphasised the circuit flow of current, often verbalising it, and drew overt attention to the direction of current flow 16 times during the course of the lessons.

Ms Brown tended to maintain a strong control over the discussion. Limiting the questioning and discussion is sometimes a result of lack of knowledge of the topic (Carlson, 1992; Sanders et al., 1993), and, although Ms Brown professed adequate knowledge, it did appear from incidental discussions that it was limited. Ms Brown's discussions were slow moving with little evidence of active participation by the students and they generally appeared unmotivated. Her range of demonstrations was restricted and the students were only involved in a very limited manner. Ms Brown put less emphasis on the circuit flow of current, although there were occasions when the idea was implied and students could have developed some understandings. She only overtly discussed it four times, although there were also five occasions when her explanation was unclear, and a further four related to the negative to positive joins in a circuit when batteries were in series.

Gage and Berliner (1992) and Swift et al. (1988) considered that classroom discussions are rarely true discussions and are often recitations, with Swift et al. (1988) considering that discussions often consist of teacher-dominated talk and low-level questioning. Neither Mr Avery nor Ms Brown conducted whole-class discussions that were true discussions. Mr Avery's tended to be explanations which explained some scientific terms (Ogborn et al., 1996) and which included a variety of levels of questions (Cunningham, 1987). Ms Brown's discussions were more like those described by Swift et al. (1988), tending to be drills with the teacher dominating the talk and using mainly

low level questions. She tended to use less scientific terms than Mr Avery, only explaining some of them. Mr Avery's monologue, at the beginning of Lesson 1h, although teacher centred was also a review of what had been learned, checking on student understanding and focussing on key concepts (Gage & Berliner, 1992) and this allowed the students to acquire more factual information about the topic under discussion (Wilson, 1987).

Mr Avery's recognition of alternative frameworks (Wilson, 1987) allowed him to accept uncritically the variety of suggestions students had for circuit flow, although he did not explain the correct answer until a student questioned his response. Ms Brown's lack of knowledge about alternative frameworks limited the discussions in her lessons. Unfortunately, only one student response per question was normally considered and students were left unaware that other ideas may be held (Vosniadou & Ionnides, 1998). This supports Assertion 5/10 (Responses from many students allows teachers to be aware of different understandings), but also introduces Assertion 8/83.

Assertion 8/83

Teachers who are less aware of alternative frameworks may, by restricting discussion either in group work or in whole-class discussion, not give students the opportunity to recognise and discuss other ideas.

The students in Mr Avery's class were attentive and interested and demonstrated their attention by asking questions and offering suggestions during the whole-class discussions and demonstrations, and during the group activities and discussions. They also volunteered information and were willing to argue points with the teacher, as well as querying the teacher's statements. Their answers to questions were detailed and often included the reasoning behind their answers, and they were involved in the construction of explanations. Mr Avery had many opportunities to recognise students' ideas. The students in Ms Brown's class did not offer extra information or participate in the discussion apart from responding to questions, and their participation in demonstrations was limited, with many talking or using the equipment. There were no occasions when they were involved in constructing clear explanations. They rarely elaborated on their answers and tended to respond with one word or fragmented answers, making the content difficult to understand. Ms Brown had few opportunities to recognise the ideas that students had. The interactions and behaviours that occurred during the teachers' visits to groups in both classes were similar, with both teachers using some open

questions and allowing students to develop their ideas (Cosgrove & Osborne, 1985h; Driver et al., 1994). Both teachers also tried to help clarify the students' thinking and ideas (Barnes & Todd, 1977), and both left the students with a variety of understandings. Mr Avery usually ensured that ideas developed in group discussions were then also included in whole-class discussions, but Ms Brown rarely did this.

When the learning outcomes are considered, the contrast between teaching styles is reflected in the opportunities for learning and the students' understandings, with Ms Brown's limited discussion resulting in a low level of understanding by most students. However, three of Ms Brown's students did make a considerable improvement in their understandings with a further two showing some improvement. This introduces Assertion 8/84

Assertion 8/84
 Even when information is not presented clearly and effectively by the teacher in the whole-class discussion, students may still improve their understanding of a concept. This may be through whole-class interactions or from interactions with other group members.

Summary

When the teachers' strategies during the whole-class discussion are compared, it is apparent that Mr Avery's strategies offered more opportunities for the students to develop understandings, with Ms Brown's strategies offering few opportunities for learning. Mr Avery explained the concepts more often and more clearly than Ms Brown. The students in Mr Avery's class were interested and involved in the discussion and participated in many of the demonstrations and activities. They developed a greater understanding of the concepts than students in Ms Brown's class who showed little interest in the proceedings, and did not participate fully in the discussions or demonstrations. They were rarely involved in demonstrations and were often unable to see them clearly (Figure 8.4).

Mr Avery	Ms Brown
Whole-Class Discussions:	
Quiet but animated discussion	Discussion not animated or interesting
Explanation of some of the scientific terms	Limited explanation of some of the scientific terms
Many open questions	Few open questions directly related to this topic
Where several answers accepted, correct answer eventually explained	Where several answers accepted, correct answer not clearly explained

Mr Avery	Ms Brown
Many closed questions	Many closed questions
Discussion involved many students in the class	Discussion often involved the same students
Control incidental	Control interrupted discussions
Clear explanations	Explanations not always clear
Current flow demonstrated and explained frequently	Current flow only demonstrated and explained infrequently
Frequent comprehensive reviews	Very limited review
Discussed focus questions with whole class	Did not discuss focus questions with the class
Knowledgeable about students' alternative frameworks	No apparent knowledge of students' alternative frameworks
Used posters, blackboard drawings, some specified practical demonstrations and extra practical demonstrations to help explanations	Some limited blackboard drawings and limited use of specified practical demonstrations to help explanations
Student Behaviours and Participation:	
Usually paid attention during whole-class discussions	Often talked and/or used equipment during whole-class discussions
Moved chairs so they faced teacher during whole-class discussions	Turned round but did not move chairs during whole-class discussions
Questioned during and physically involved in teacher demonstrations	Very limited involvement in teacher demonstrations
Close to demonstrations	At desks for demonstrations
Asked questions (other than procedural)	Only asked procedural questions
Offered extra information	Offered very limited information
Willing to argue points with Mr Avery	Rarely spoke outside teacher questions
Showed interest and enthusiasm	Showed little interest in the discussions
Gave full answers that were justified	Gave only limited factual answers
Generally drew diagrams on blackboard whilst other students still working	Spent considerable time watching other students draw on board
Questioned about blackboard drawing	Limited discussion about blackboard drawings
Interactions during Group Work:	
Mr Avery ensured all groups knew what they were meant to be doing/using by repeating instructions to individual groups as necessary.	Ms Brown ensured all groups knew what they were meant to be doing/using by repeating instructions to whole class and individual groups
Mr Avery monitored the progress of work	Ms Brown monitored the progress of work
Teacher and student utterances similar in quantity	Teacher and student utterances similar in quantity
Mr Avery used some open questions that might develop understandings	Ms Brown used some open questions that might develop understandings
All information given to whole class	Some instructions/information given to groups not given to whole class
No answers sometimes reached during group discussions but clear explanations usually given in whole-class discussion	Usually no definite answer reached during group discussions, and unclear explanations in whole-class discussion

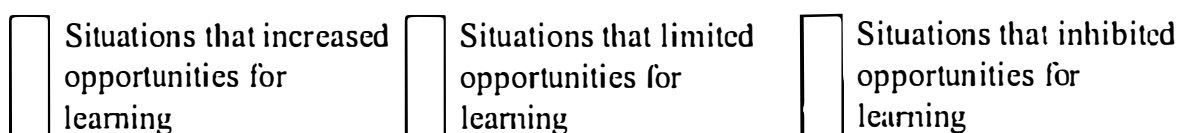


Figure 8.4. Teacher and student behaviours during the teaching of Proposition 5

The two teachers' behaviours when visiting groups were similar and neither teacher always reached closure in their discussions with groups. However, Ms Brown did not pass on all the information and instructions given to individual groups to the whole class, whereas Mr Avery's clearer explanation and dissemination of information

to the whole class meant that his students had more opportunities to develop understandings (Figure 8.4).

Mr Avery allowed the students more opportunities to generate understandings than Ms Brown and involved them in mutual construction of explanations. He allowed students more opportunity to realise that there were other ideas that could be considered and engaged in discussion that was of a higher quality than that of Ms Brown (Figure 8.4).

Mr Avery's Teaching of Propositions 2 and 3: Concepts Relating to the Amount of Current in Parts of a Circuit and Concepts Relating to Joins in a Circuit

Introduction

Generally, Mr Avery was a competent teacher who taught the concepts well. The class results for Proposition 2 only showed a small improvement, with the pretest mean being 1.12 and the posttest 2.08 of a possible maximum score of eight, indicating that the students' learning for this proposition was limited. The class results for Proposition 3 indicate that the teaching of this proposition was more effective with the pretest mean score being 0.44 and the posttest 3.24 out of a possible maximum score of seven.

Mr Avery's Teaching of Proposition 2: The Amount of Electric Current in any Part of the Circuit will be the Same.

This proposition was in two parts, the amount of current in the wires in a circuit and the amount of current in a battery in a circuit. The amount of current in the wires was intended to be covered mainly in Lesson 1, although the ammeter demonstrations in each lesson should have served to emphasise this and it could have been reinforced in most lessons. The amount of current in a battery was included in the Lesson 3 outlines where the students worked on series circuits. Both concepts were only covered in a limited fashion and at no stage did Mr Avery specifically state that the amount of current in all parts of the circuit was the same (Figure 8.6).

Lesson 1a

After the students had constructed circuits with one wire, one battery and one globe in Lesson 1a, Mr Avery asked them to discuss where the current was in the circuit and the direction in which it was flowing. Although Mr Avery circulated and talked to some groups, he only discussed the direction of current flow and not where it was in the circuit. The Focus Group did not engage in this discussion, and, since it was not covered in the ensuing class discussion, the amount of consideration the rest of the groups had

given to the subject is unknown. Mr Avery did follow the suggested directions of current flow on the blackboard diagrams and his statements could have indicated that the amount of current was the same throughout the circuit, but it was only weakly implied and it would be unlikely that the students would recognise it:

Mr Avery It (the current) comes from here, this negative part, and it goes right around, in through the filament and back through there. (Lesson 1a)

During the ammeter demonstration in this lesson, which was designed to show that electric current did not get used up in the globe, he showed the ammeter readings to all the groups whilst explaining what was happening:

Mr Avery (Indicating the needles on the two ammeters) So it tells us that we've got some energy flowing. If the energy coming in from this side, it's just on one mark below the two and there it's on one mark below the two. So the energy going in at one end is the same as the energy coming out the other end (Lesson 1a)

This implied that the current in the wires was the same but the term electric current would have been easier for the students to understand and the term 'energy' was used incorrectly.

FOCUS QUESTIONS

What was needed to make the globe light?

Where did the joins have to be?

What do we call this type of construction?

Where do you think the electric current was travelling to from?

What makes you think that?

When the globe is lit is there an electric current in the battery?

Why do you think that?

Is there an electric current in the battery when the globe isn't lit?

Why do you think that?

When the globe is lit is there an electric current in the wires?

Why do you think that?

Is there an electric current in the wires when the globe isn't lit?

Why do you think that?

Do you think the electric current was the same in the two wires in activity 2 or were there different amounts of current in the wires?

Why do you think that?

Figure 8.5. Focus questions given to the groups in Lesson 1a.

Mr Avery used the focus questions from the lesson outlines to help direct the group discussion at the end of the lesson (Figure 8.5). He circulated to ensure the students were on-task, but did not discuss the concepts with the groups. The only group recorded, the Focus Group, did not reach the relevant questions in their discussions.

The whole-class discussion at the end of Lesson 1a did not reach the questions related to the amount of current in the wires so the topic was not discussed further and student ideas were not addressed. During this lesson Mr Avery explained that electricity was the flow of electrons, a statement which the students wrote in their workbooks in Lesson 1b. This was an essential understanding for the role-play activity in Lesson 1b.

Lesson 1b

Mr Avery's explanation at the beginning of Lesson 1b (p. 198) also weakly implied that the current was the same. He clearly explained the direction of current flow and it could have been construed to mean that the current remained the same throughout the circuit. However, this is unclear and the concept of electrons slowing down would be confusing to the students. Immediately after this a student asked how a battery ran down:

Mr Avery We're actually using the energy that's stored there. The electrons still go back and they get replenished. (Lesson 1b)

Again, the statement implies that something within the circuit would stay the same, but it is unclear, with no explanation of how electrons 'get replenished'. Mr Avery often appeared to use energy and electrons interchangeably and, although his explanation demonstrated the difference, it may have confused the students.

The role-play was designed to demonstrate that the amount of current in a circuit always remained the same. Before the role-play, Mr Avery explained what it was intended to show and, as the electrons moved through the circuit, explained that they were picking-up energy from the battery and the globe was using the energy and, at the end, clarified what happened in a circuit:

Mr Avery Eleven. So we had eleven electrons go through that side. They didn't get used up. The electrons didn't get used up, just the energy that they got from the
Student Battery
Mr Avery supply. Then they continued through here and the electrons came back and we continued until I broke the circuit. (Lesson 1b)

Lesson 3

The concept that the amount of current in batteries in a circuit was the same as in other parts of the circuit was also covered in a limited way. About half way through Lesson 3 Mr Avery followed the flow of current in a circuit through the batteries and, although the amount of current was not mentioned, the explanation implied the current stayed the same. However it was not stated and students with little understanding would not have recognised the explanation:

Mr Avery Let's trace the path of the circuit. We said negative, okay, here it is. Negative, positive. The electrons, we said, were flowing in this direction through here, across there, out went to here, which is the positive goes to the negative goes to the positive and goes through. (Lesson 3)

The concept was discussed at the end of the lesson during the whole-class discussion using the focus questions. However, the explanations were unclear. A student stated that the more batteries that were used the brighter the globe would be:

Mr Avery You remember that little exercise we did with the electron (the role-play). We said a battery gives out these little electrons. So, obviously, if I've got two batteries I'm going to have twice the amount of electrons coming out; if I have three batteries I'm going to have three times the amount of electrons coming out and therefore those electrons are the things that are causing the globe to shine. Was there the same amount of energy in each battery in the circuit?

Student Yes

Mr Avery Well, there should have been shouldn't there because each was marked 1.5 volts on it. (Lesson 3)

He initially stated that the batteries all had the same amount of electrons, and, immediately afterwards, stated that they each had the same amount of energy with no further explanation.

Remaining lessons

Although there was some discussion of electron flow in circuits in Lesson 3/4, there was no information that might have improved or changed the students' ideas.

Mr Avery's explanation in Lesson 4 considered the number of electrons a battery produced:

*Mr Avery In series it means we're adding a 1.5 volt battery to a 1.5 volt battery which gives us a 3.0 volt battery. Okay, it gives us a lot more *. It means that we're going to be adding more electrons to go through because this battery produces let's say twenty electrons and this one's going to produce twenty electrons, therefore we've forty in total therefore the light globe's going to light up very brightly. (Lesson 4)*

Although Mr Avery's interactions with the groups did involve conceptual discussion, there was no discussion of the amount of current in the circuit.

Summary of Teaching

It is apparent, when the transcripts are examined, that this concept was not addressed well during the activities or the discussions that occurred. It was rarely covered overtly and the explanations were unclear (Figure 8.6).

Lesson/ Record	Activity type	Participants	Activity or discussion details
1a	Group activity	SS	Constructed simple circuits with one wire, a battery and a globe
	Group discussion	SS	Direction of current flow and where it is in a circuit
1a	Focus Group		No relevant discussion
1a	Whole-class discussion		No relevant discussion
1a 554&572	Ammeter demonstration	T	• <i>The current in both sides of the circuit is the same</i> (stated twice)
1a 626	Whole-class discussion	T	• <i>The flow of current is the flow of electrons</i> Weak implication that current stayed the same
	Group activity	SS	Groups generated answers to question sheet, may not have reached relevant question
1a	Focus Group		No relevant discussion
	Whole-class discussion		Discussed question sheets - no relevant information
1b 32-35	Whole-class review	T	• <i>Electrons flow through the circuit</i> • <i>Energy gets used up in the circuit</i> • <i>Electrons continue through the circuit and get replenished in the battery</i> Weak implication that current stayed the same
1b 94-141 1b 142-158	Role-play	T/SS T/SS	Indicated electrons flowed right round a circuit • <i>Electrons do not get used up only energy</i>
3	Group activity	SS T	Connected batteries in series. Circulated and discussed amount of electrons flowing through the batteries with one group
3	Whole-class discussion	T	Followed flow of current through a series circuit. Weak implication that current stayed the same
3 801	Whole-class discussion	T	• <i>Two batteries would have twice the electrons and three batteries would have three times the electrons</i>
3 802-804		T	• <i>The amount of energy in each battery was the same</i>
4	Group activity	SS	Connected batteries in parallel
4 156	Whole-class discussion	T	• <i>In series the voltages of the batteries are added together</i> • <i>A battery produces, for example, 20 electrons therefore two batteries will produce 40 electrons</i>
4 156		T	

Note: • Indicates explanation generated or offered

Participants: T - Mr Avery, S - Individual student, SS - Several students, , T/SS Mr

Avery and one or more students



Concept discussed or demonstrated



Concept implied



Concept not discussed or incorrect statements

Figure 8.6. Summary of activities and interactions which provided opportunities for developing understanding of Proposition 2.

Changes in Students' Understandings

In the pretest for Question 5, the question relating to current flow in the batteries, nine students made the correct choice although only one gave an acceptable explanation. In the posttest 14 students, 56% of the class, made the correct choice, with eight students offering a limited explanation and three unable to offer any explanation (Table 8.4). The level of explanation varied:

Ann *Because electricity has to flow through all 3 batteries to reach/power the globe and once it reaches it it just keeps flowing, it doesn't just stop because the electric current is even among the batteries.*

IM16 *They all produce 1.5 V of energy*

Three students made an incorrect choice in the posttest but did not offer understandable explanations and three felt that the energy built-up as it passed from battery to battery resulting in the battery closest to the globe having the most energy. One student still stated that, for the globe to work, all the batteries must have the same amount of energy. Three students offered idiosyncratic explanations and one did not respond to the question.

Table 8.4

Type and Number of Student Responses to Q 5 and Q 10 from Mr Avery's Class on the Pre and Posttests (n = 25)

Type of response	Numbers of responses			
	Q 5		Q 10	
	Pretest	Posttest	Pretest	Posttest
Correct response	9	14	6	12
Batteries: The battery closest to the globe has the most current	6	3		
Batteries: All batteries must have the same current for the globe to work	4	1		
Wires: The electric current is used up in the globe			1	3
Wires: Current comes from both ends of the battery			9	2
Wires: Current only comes from one end of the battery			1	0
Idiosyncratic answer	5	3	1	6
Invalid answer	0	3	5	1
No response	1	1	2	1

Question 10 assessed student understandings of the amount of electric current in wires either side of a globe. In the pretest six students made the correct choice, with no student offering an acceptable explanation. In the posttest, 12 students made the correct choice with four of these giving explanations that were not understandable (Table 8.4). Again the level of explanation varied although only two students gave an answer that indicated a reasonable understanding. Generally the level of explanation was low:

IM14 The same amount of current goes through the wires

IF26 It goes around in circles

Of the remaining students, three considered that all or some of the electric current was used up in the globe and two had a bi-polar view of current flow and considered that the same amount of current would come from each end of the battery. Six students offered idiosyncratic explanations.

The pretest mean for this proposition was 1.12 with the posttest mean being 2.08 out of a possible score of eight. Although several students changed their choice, the low level of the explanations resulted in only a limited improvement in the scores.

Mr Avery's Teaching of Proposition 3: Joins in a Circuit Consisting of Wires, Batteries and Globes Need to be at Specific Points on the Batteries and Globes to Result in a Working Circuit.

Mr Avery discussed this proposition in detail in Lessons 1a and 1b, with further limited discussion in later lessons (Figure 8.7). In Lesson 1, students completed activities using globes with no globe holders and could see all the connections. Once globe holders were introduced in Lesson 2 the globe connection points were no longer visible although those on the battery were. A poster was supplied showing a diagram of a simple circuit (Appendix 3) which showed the globe connections and which was constantly used by Mr Avery to show the path of current flow in circuits.

Lesson 1a

The first group activity was to construct working circuits using a battery, one wire and a globe. Mr Avery had drawn diagrams of possible methods of construction clearly showing joining points, although not all of the diagrams were of working circuits. Students were asked to work in their groups to construct and test circuits to find those that worked. Most students worked in pairs as there was enough equipment available and they tended to use the diagrams on the blackboard as a guide and tested

those, although some started to experiment further. The data from the Focus Group indicate that, although the students worked in pairs, they were interacting as a group.

During the time the groups were constructing circuits, Mr Avery circulated round the classroom ensuring that the groups were using the correct equipment and that they understood what they were doing, sometimes announcing to the class when a group had managed to light their globe. He did not, at this stage, offer help to the groups but encouraged them to keep trying to construct a working circuit. He was also aware that some students were competent at the activity and challenged them:

Mr Avery: Righto. For those clever people who have found two ways, in actual fact there are, see if you can find four ways. (Lesson 1a)

The student responses indicated the range of expertise in the class:

Student 1 I've found three.

Student 2 I've found two.

Student 3 I haven't found any.

Student 4 I've found three. (Lesson 1a)

Later, as he visited the groups, he asked them to demonstrate their circuits with some students enthusiastically explaining how they had been constructed.

Mr Avery stopped the activity after about four minutes and asked individuals to indicate, by adding yellow light rays to the diagrams, which circuits drawn on the blackboard would light a globe. There was no discussion at this stage but most of the class were attentive and were offering advice to the students working at the blackboard. Mr Avery asked a student to read out the full instructions for the activity which asked the students to draw all the circuits that they made. Mr Avery reiterated the instructions indicating that they needed to draw diagrams of any circuits that they had constructed. He suggested they use the blackboard diagrams and that they may need to test them again, but they also needed to draw other circuits that they had constructed. Once again he circulated to ensure that the students were following instructions.

After some group discussion of direction of current flow, Mr Avery used a cardboard template of a battery and one of the working circuit diagrams drawn on the blackboard to discuss current flow and indicated the joining points, incidentally naming the joining points on the battery. When following the circuit with his finger for each possible circuit flow suggested by the students he again indicated the joins. He then asked the students whether two new circuits that he had drawn would light the globe.

Mr Avery asked the students to look at their equipment and see if they could explain where the joining points needed to be on a globe for it to light and received answers from several students, summarising them as:

Mr Avery *Okay, the metal casing on the outside, any part of the metal casing. And where's the other one?*

Student *On the bottom, that little um grey bit.*

Mr Avery *Okay, see the little silver part, the little grey part down there (indicating). (Lesson 1a)*

He then followed a circuit through with his finger, again indicating the battery joins although not naming them.

The second activity was to build a circuit using a battery, two wires and a globe with the globe not touching the battery, and record all the circuits constructed, with most students again working in pairs. The groups were allowed just over nine minutes for this activity and, this time, as Mr Avery visited the groups, he asked questions to direct the students' attention to their errors:

Mr Avery *Right, you've got your two wires. It's not working. What did we say about the globe? What are the important parts of the globe that need to be connected? Okay, now try it. (Lesson 1a)*

Mr Avery asked individuals within the groups to demonstrate the working circuits they had constructed, accepting any that were using incorrect equipment but also suggesting they use the right materials. He also checked students' diagrams and, where the joins were incorrect, pointed out the errors and asked the students to correct them.

Whilst the class was still working Mr Avery asked four students, including three Focus Group members, to draw working and non-working circuits on the blackboard. Jon, from the Focus Group, was asked to draw a working circuit but drew a non-working circuit. When these were completed, the students packed away and turned their chairs to face the blackboard. They were asked to decide whether the circuits drawn on the blackboard would work or not and, if a diagram was not a working circuit, a student was asked to correct the diagram, moving the joins to the correct points. Bob, from the Focus Group, corrected Jon's diagram. Mr Avery specifically referred to the joining points on both the battery and the globe when he described why the circuits were now working.

During the next part of the lesson Mr Avery used the ammeters to demonstrate current flow through a circuit. Although the connections were not visible Mr Avery did

talk about the joining points on a battery, referring to the positive and negative terminals, terms which had been used previously when the class discussed direction of current flow. At the end of this segment of the lesson, he used one of the blackboard diagrams to show the flow of current, again showing the joining points of the circuit.

The groups were then given a photocopied sheet of the focus questions and were asked to discuss them and write the answers on the sheet (Figure 8.5). Again, Mr Avery circulated through the groups and ensured they were on-task although he did not get involved in the discussion. The amount of input from individual students may have varied as was demonstrated in the Focus Group. Initially, the group members were all involved but, because of a lack of support from group members, Pat's contributions diminished as the discussion progressed, although she did still listen:

- Sue* Um. Where did the joins have to be?
Pat On the side and on the
Jon One to the positive one to the negative.
Bob Positive and negative.
Pat Was it, are you listening to me?
Jon Write positive and negative.
Pat Would it be from the globe.
Jon Look, where's a battery? Look how it's got that on there that's positive.
Pat Yeah.
Jon So that's where the current goes to from that end to that end. It flows from there to there.
Sue Okay.
Pat I know. (Lesson 1a)

In this case the joins to the globe were ignored because of Jon's domination of the talk.

The focus questions were then discussed as a whole-class, although this was not completed as the end of day siren went. However, the parts relevant to the construction of a working circuit and the position of the joins were the first two questions and they were covered with the students responding correctly. The students had turned their chairs to face Mr Avery and most were paying attention. Mr Avery, once again, used one of the blackboard diagrams to show the current flow through a circuit.

Lesson 1b

In the follow-up lesson (Lesson 1b) shortly after the main activity lesson, Mr Avery discussed electricity in general with the class, but within that discussion he used the supplied diagram of a simple circuit to follow the flow of electric current, incidentally showing and naming the joins:

Mr Avery Now a circuit, as we can now establish, has to be a circle of movement for the electrons. There it is (following circuit diagram). From our negative part of our battery it flows through the wire into the casing of the globe, around the filament which produces the light, so some of these electrons are slowed down using the light, and then the electrons continue on and go to the battery. (Lesson 1b)

He did this a second time shortly before asking the students to copy the diagram of a simple circuit and the two statements about electric circuits from the blackboard.

During the whole-class discussion, not all the students were on-task, with some completing their title pages for the science topic and others trying to produce static electricity. However, the students generally worked well during the recording part of the lesson. Mr Avery circulated round the students checking their work and helping with any difficulties, with all students copying the joins correctly.

After the role-play activity the groups were allowed seven minutes to discuss the Summary Sheet for the lesson which showed a torch which was incorrectly connected to an external globe. The students were asked to discuss why it did not work and suggest a way of correcting it. Mr Avery circulated to ensure the students were on-task and knew what they were doing. After the group discussion he gained the class's attention and conducted a whole-class discussion on the topic. Initially students were trying to explain verbally what the problem was and how to solve it, with rather unclear explanations:

Student Jo 'I'll need two wires oh (pause) Start from the torch, from the inside of the torch and it's attached on both sides of the globe (pause) er no
Mr Avery On the casing and on the
Student On the casing. (Lesson 1b)

Mr Avery then drew the diagram from the sheet on the blackboard and asked a student to come and draw her solution. She drew all the connections correctly as did the second student with her solution. The students were attentive as Mr Avery described the circuits whilst the students were drawing and then used the second diagram to follow the circuit flow, going through the joins. Of 18 Summary Sheets completed and handed in, 10 demonstrated that students recognised that the circuit in the diagram would not work and reasonable alternatives were offered:

IF8 Because it (the globe) is not touching the case (of the battery) then you must have two wires.
IM12 Because she doesn't have the negative wire.

A further six recognised that that the circuit diagram would not work but three drew new circuits that were incorrectly connected and the remainder did not draw a new diagram. Two Summary Sheets which had no written work had diagrams indicating that the students had not understood the basic structure of a simple circuit.

Remaining lessons

From Lesson 2 onwards the students used globe holders in the circuits. At the beginning of Lesson 2, Mr Avery briefly reviewed the connections necessary to allow a globe to light. During the first activity the students were constructing simple circuits and extending them and, as Mr Avery visited the groups, he questioned some students about the circuits and globe holders, explaining how the globe holders worked. Mr Avery repeated this explanation during the whole-class discussion after the first activity, directing the students to look at the parts of a globe holder and showing how the connections were made within the holder. At the end of the lesson, prior to reviewing the lesson activities, Mr Avery used the supplied diagram of a simple circuit to show the flow of electric current pointing out the joining points and describing the circuit:

Mr Avery Okay, what we did today was again continue that idea of a circuit as we have over here. (indicated supplied diagram) The battery, from the negative, we have it going through the casing, through the filament, which uses the energy to light up the globe. Then back out through the bottom tip of the globe, right through back to the battery' (Lesson 2)

In the remaining lessons students were constantly constructing and drawing diagrams of circuits which would have reinforced their understanding of the joining points, although, as globe holders were used, the globe connections were not visible. Most student diagrams and the blackboard drawings produced by Mr Avery tended to have globe holders drawn in rather than the globe and Mr Avery used these to show current flow and, incidentally, show joining points. However, he also frequently used the supplied diagram which did not have a globe holder.

Summary

When analysing the transcript data it was apparent that this concept was covered in detail. There were frequent opportunities for the students to recognise the correct joining points on a circuit which Mr Avery described overtly, and also incidentally when demonstrating current flow using diagrams (Figure 8.7).

Lesson/ Record	Activity type	Participants	Activity or discussion details
1a	Focus Group	Jon & Bob	Constructed a working circuit
1a	Whole-class discussion	T	Instructions to construct circuits using one battery, one wire and a globe.
1a	Group activity	SS T	Constructed simple circuits with one wire, a battery and a globe. Circulated ensuring groups on task. Asked students to demonstrate working circuits.
1a		T	Challenged students to make four different working circuits.
1a	Focus Group	All	Worked in pairs to construct working circuits. No discussion of joining points
1a	Whole-class discussion	T/SS	Students identified which of the circuits drawn on the blackboard worked and which did not.
1a	Group activity	SS	Students tested and recorded working and non-working circuits
1a	Focus Group	All	Constructed circuits. No relevant discussion
1a	Group discussion	SS	Direction of current flow and where it is in a circuit
1a	Focus Group	All	Continued recording, did not discuss topic
1a	Whole-class discussion	T T/SS	Reminder to discuss topic Generated understandings of what an electric current was
1a	Group discussion	SS T	Direction of current flow and where it is in a circuit Circulated and questioned and then drew two more circuits on blackboard.
1a	Focus Group		Continued recording, did not discuss topic
1a 266,270, 275) 1a 280-289)	Whole-class discussion	T SS T	Referred to positive and negative on battery when discussing direction of flow. Identified working and non-working circuits drawn on blackboard. Followed suggested current flow on circuit diagrams three times incidentally showing joins.
1a 290) 1a 291-292) 1a 296) 1a 298) 1a 297&299) 1a 301)		T S S S T T	Where are the joining points on the globes? <ul style="list-style-type: none"> • Little spring (filament) • Metal casing • Grey/silver bit • On the metal casing and on the silver grey bit Traced circuit on blackboard diagram with his finger on blackboard diagram, incidentally indicating joins.
1a	Group activity	SS T	Constructed simple circuits with two wires, a battery and a globe, recorded working and non-working circuits. Circulated, helping and advising and checking diagrams
1a	Focus Group	All	Working in pairs or individually to construct circuits. Recognised that some connections result in hot wires.
1a	Group activity	SS	Selected students including Sue, Jon and Pat. drew working and non-working circuits on the blackboard
1a 494-531) 1a 494-531)	Whole-class discussion	T/SS SS	Identified working and non-working circuits on the blackboard Corrected blackboard diagrams by changing position of joins. Bob corrected Jon's diagram
1a 538-621) 1a 625)	Ammeter demonstration	T	Contact points not visible Current flows from negative to positive.
1a	Group activity	SS	Groups generated answers to question sheet
1a FG570-582	Focus Group	All	Only discussed battery joins in detail no globe joins
1a 679-697 1a 749	Whole-class discussion	T/SS T	Discussed question sheets joining points in a circuit Joins need to be on the positive and negative of the battery and on the casing and grey part of the globe Followed current flow in circuit on blackboard diagram, showing joining points
1b 22,32, 61	Whole-class review	T T	Followed current flow in circuit on blackboard diagrams with his finger three times Described all circuit joins twice, battery joins once more
1b	Group activity	SS T	Copied the supplied diagram and blackboarded statements Circulated, helping as necessary
1b	Focus Group	All	Copied diagrams.

Lesson/ Record	Activity type	Participants	Activity or discussion details
1b	Group activity	SS	Groups discussed and generated solutions to problems on Summary Sheet including joining points in a circuit
1b FG53-97, 105-145	Focus Group	All	Discussed the problems on the sheet and generated group responses. All completed the sheet
1b 207-216	Whole-class discussion	S	Corrected battery joins on torch diagram on blackboard producing possible solution.
1b 222		S	Drew possible solution on blackboard
1b 231		T	Described and followed two current flow possibilities on student diagram incidentally showing joining points
2 5	Whole-class introduction	T	Stated joining points on battery and globe
	Group activity	SS	Constructed a simple circuit to test conductors using a globe holder and two wires in one side of the circuit
2 377&389 2 378-389	Whole-class discussion	T T/SS	Explained and demonstrated joins in globe holder • <i>When the globe is unscrewed the circuit no longer works</i>
	Group activity	SS	Tested for conductors and insulators
2 921	Whole-class discussion	T	Described circuit and joins using poster
3 16	Whole-class review	T	Traced circuit on poster with his finger incidentally showing joining points
	Group activity	SS	Completed globes in series activity
3 524&526	Whole-class discussion	T	Followed current flow through two series circuit diagrams on blackboard with his finger, incidentally showing joining points.
	Group activity	SS	Completed batteries in series activity
3 811 3 812-814	Whole-class discussion	T T/SS T/SS	Traced circuit on torch poster with his finger • <i>A circuit is a continuous circle</i> • <i>Joins to the globe are through the globe holder</i> • <i>When the globe is unscrewed the circuit is cut</i>
3/4a	Group activity	SS	Connected globes in parallel
3/4a 453	Whole-class discussion	T	Followed current flow on blackboard diagram with his finger incidentally showing joining points.
	Group activity	SS	Connected globes in series
3/4a 653 3/4a 684 3/4a 685-692	Whole-class discussion	T T	Followed current flow on blackboard diagram with his finger incidentally showing joining points. Used bridge analogy, followed current flow in circuit on blackboard diagram with his finger incidentally showing joining points.
3/4a 694-705		S	Student suggested an alternative parallel circuit and drew on blackboard
3/4a 706		T	Followed current flow in parallel circuit on blackboard diagram with his finger partially using bridge analogy incidentally showing joining points.
3/4b 40-47 3/4b 50	Whole-class review	T/SS T	<i>When the globe is unscrewed the bottom metal bit of the globe holder is no longer connected</i> Followed current flow in circuit on diagram of parallel circuit with his finger incidentally showing joining points.
4	Group activity	SS	Connected batteries in parallel
4 585	Whole-class discussion	T	Followed current flow on blackboard diagram with his finger incidentally showing joining points

Note: • Indicates explanation generated or offered

Participants: T - Mr Avery, S - Individual student, SS - Several students,

T/SS Mr Avery and one or more students

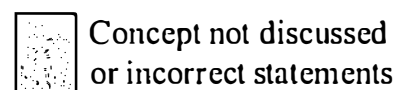
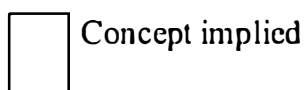
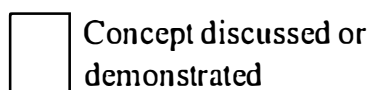


Figure 8.7. Summary of activities and interactions which provided opportunities for developing understandings of Proposition 3.

Changes in Students' Understandings

The teaching and activities used resulted in 18 students (72%) of the class demonstrating a scientific understanding in the posttest with 56% actually changing to a scientific view (Table 8.5). The four students who retained their scientific view gave explanations that demonstrated improved understanding:

Pretest

IF2 I chose these two because they are practically wired the same way with one wire attached to the bottom of the globe and the other to the side

Posttest

IF2 Because they are connected in a circuit negative to positive

Eight students demonstrated a good or developing understanding, with the remaining 10 offering limited explanations:

IF1 Because they aren't connected properly

IF26 Because of the way they are connected

Table 8.5

Type and Number of Student Responses to Questions 7a and 7b from Mr Avery's Class on the Pre and Posttests (n = 25)

Type of response	Number of responses			
	Q 7a		Q 7b	
	Pretest	Posttest	Pretest	Posttest
Correct	4	18	3	18
Joins can be anywhere on the globe	1	1	1	1
The circuit must have two wires	4	3	3	3
Only one wire is needed from the battery to the globe	1	0	1	0
Idiosyncratic	6	2	6	2
Invalid answer or no response	9	1	11	1

One student did not respond to the question. Three of the students who still had alternative frameworks after the teaching sequence did not consider that the globe sitting on the positive terminal of a battery and connected to the negative terminal with a wire would work. This was only covered in the first part of the first lesson and was not discussed further. One student considered that if the wires were connected to the sides of the globe from the positive and negative terminals of the battery the globe would light. The remaining two students gave idiosyncratic explanations.

The pretest mean score for this proposition was 0.44 and the posttest mean was 3.24 out of a possible score of seven.

Comparison of Changes Between Propositions

A higher percentage of students made the correct choice for Proposition 2 than for Proposition 3 in the pretest. However, the number of students who changed to a correct understanding for Proposition 2 in the posttest was less than that for Proposition 3, with an increase of 16% for Question 5 and an increase of 24% for Question 10. The posttest improvement for Proposition 3 was substantial, with 56% more students making the right choice for Question 7a and 60% making the correct choice for Question 7b. (Table 8.6). Although the number of students making the correct choice for Question 5 and 10 on the pretest was higher than that for Questions 7a and 7b, there was ample room for improvement.

Table 8.6
Changes in Students’ Understanding of Propositions 2 and 3

Proposition 2				Proposition 3			
	Pretest	Posttest	Change		Pretest	Posttest	Change
Question 5				Question 7a			
Correct choice	10(40%)	14(56%)	4(16%)	Correct choice	4(16%)	18(72%)	14(56%)
Question 10				Question 7b			
Correct choice	6(24%)	12(48%)	6(24%)	Correct choice	3 (12%)	18(72%)	15(60%)

The quality of explanations given was considerably better for Proposition 3 than for Proposition 2 with the mean for Proposition 3 increasing by 2.8 whereas the mean for Proposition 2 only improved by 0.86. Again, the pretest mean for Proposition 2 was higher than that for Proposition 3, but there was ample room for improvement.

Discussion

The analysis of Mr Avery’s teaching of Propositions 2 and 3 has demonstrated how the quality of teaching may vary when one teacher is addressing different understandings. The two propositions were very different with Proposition 2 being a more abstract concept than Proposition 3, which was visible and practical. However, Mr Avery demonstrated his competence at teaching more abstract concepts with other propositions and the poor improvement in understanding in Proposition 2 could have been improved if more attention had been paid to the proposition. Mr Avery’s rapport with the students did not change during the teaching of these two propositions and, in

fact, both propositions should have been addressed initially during the first lesson with further explanations during later lessons. However, the amount of attention each proposition received was very different. Although he asked the students to discuss the amount of current in the various parts of the circuit (Proposition 2) in their groups, it did not get referred to overtly in any of the whole-class discussions and he did not bring it to the students' attention during his group visits. The only time this concept was overtly addressed was in the role-play. If the curriculum materials had been followed, the topic would have been covered in more depth. Mr Avery was knowledgeable about electric circuits and it is unlikely that this omission was caused by a lack of knowledge (Arditzoglou & Crawley, 1990; Gilbert et al., 1987; Smith & Neale, 1989) and it may have been omitted only because he had not referred to the teaching materials. This may be a problem when teachers are familiar with the topic and do not read the lesson guides carefully. Proposition 3 was discussed in detail, both during the whole-class discussion and during Mr Avery's visits to groups, with Mr Avery using a variety of strategies to illustrate this concept. He also frequently reviewed it, including covering the relevant focus question during the end of lesson review in Lesson 1. Mr Avery did not overtly discuss Proposition 2 at any time although it was referred to indirectly, and it was not discussed during the end of lesson review.

The students did not change their behaviours and attention but the lack of overt explanations and discussion about Proposition 2 allowed the students few opportunities to develop understandings either during the whole-class discussion or group work. Although Mr Avery's explanation at the end of the role-play (p. 219) explained that the electrons did not get used up, the explanation was limited and the students had no opportunity to become involved in the discussion as it was a teacher explanation with no questions. The students had opportunities to discuss concepts and engage in activities related to Proposition 3 in their groups, and Mr Avery frequently reviewed it when visiting groups, but they had little opportunity to engage in group discussions of Proposition 2. The Focus Group, and possibly other groups, did not get this far when they were discussing the focus questions, and these data introduce Assertion 8/85.

Assertion 8/85

Sufficient time needs to be allowed in all lessons for the students to engage in discussion and reflection.

When the learning outcomes are considered, the lack of attention paid to Proposition 2 is reflected in the limited improvement in understandings that the students demonstrated, with eight of the 14 correct choices having inadequate explanations.

The students developed more scientific understandings for Proposition 3 with 18 students making the correct choice and none giving inadequate explanations.

Summary

Mr Avery only engaged in limited discussion of Proposition 2 compared to Proposition 3 and used fewer strategies which would provide opportunities for the development of understandings (Figure 8.8). It is apparent that the whole-class discussions in the lessons did not give the students the opportunities to find out about the amount of electric current in various parts of a circuit. However, they had many opportunities to be involved in activities related to joins in a circuit (Figure 8.11).

Because of the lack of discussion and activities relevant to Proposition 2, Mr Avery’s interactions with the groups were very limited. There were far more opportunities for him to be involved in the activities and discussions related to Proposition 3 (Figure 8.8).

Teaching Proposition 2	Teaching Proposition 3
Whole-Class Discussion:	
Friendly to students	Friendly to students
Control incidental	Control incidental
Very limited overt discussion of topic	Quiet but animated discussion
No open questions	Limited open questions
No questions about topic	Many closed questions
Weak or limited explanations of concept	Clear explanation of position of joins
Limited weak mentions of topic	Frequent clear discussions of topic with incidental and overt identification of joins
Indirectly used posters and blackboard drawings, when mentioning topic	Used posters, blackboard drawings, some specified practical demonstrations and extra practical demonstrations to help explanations
Explanation of some of the scientific terms which were used inconsistently by Mr Avery	Explanation of some of the scientific terms which were used consistently by Mr Avery
No student input to discussions	Discussion involved many students in the class
Knowledgeable about students' alternative frameworks but did not use knowledge	Knowledgeable about students' alternative frameworks and used this knowledge
No opportunities to recognise direction of current flow	Provided many opportunities for students to recognise joining points for themselves
Used ammeter demonstration to imply concept	Not relevant
Limited reviews which only weakly recognised topic	Frequent comprehensive reviews within initial lesson and in other lessons
Whole-class focus question discussion did not reach this topic	Discussed focus questions with whole class
Role-play demonstrated current the same, explained by Mr Avery	Not relevant
Not relevant	Whole-class discussion of Summary Sheet

Teaching Proposition 2	Teaching Proposition 3
Student Behaviours and Participation:	
No appropriate discussion	Moved so they faced teacher
No opportunity	Showed interest and enthusiasm
Not relevant	Drew diagrams on blackboard whilst other students still working
Not relevant	Questioned about and physically involved in evaluating and correcting blackboard drawings
No opportunity	Questioned during and physically involved in teacher demonstrations
Close to role-play	Close to demonstrations
Usually paying attention	Usually paying attention
Focus questions used to direct final discussion but topic may not have been reached in group focus question discussions	Focus questions used to direct final discussion
No opportunity	Copied diagrams that addressed concept
No opportunity	Offered extra information
Not all groups followed teacher instructions for discussions	Most groups followed teacher instructions for written and practical activities and discussions
No Summary Sheet questions	Whole-class discussion of Summary Sheet addressed concept
Interactions during Group Work:	
Not relevant	Mr Avery checked and questioned students about incorrect diagrams
Mr Avery did not check that students were discussing this topic	Mr Avery ensured all groups knew what they were meant to be doing/using by repeating instructions usually to individual groups as necessary.
Mr Avery did not monitor discussion	Mr Avery monitored progress of work
Not relevant	Mr Avery assisted groups that were having difficulties and encouraged groups to keep trying for a working circuit
The limited information given to a group also given to the whole class.	Information given to groups also given to whole class
Not relevant	Gave students opportunities to demonstrate the construction of their working circuits
Not relevant	During activities encouraged and challenged students as a class
Only limited discussion with one group	Discussed joins with many of the groups

☐ Situations that increased opportunities for learning
 ☐ Situations that limited opportunities for learning
 ☐ Situations that inhibited opportunities for learning

Figure 8.8. Teacher and student behaviours during the teaching of Propositions 2 and 3

The last four chapters have looked at the interactions that occurred in the three classes. Chapter 9 considers the impact of these interactions on student understanding by examining the conceptual changes that occurred in the three classes for all propositions.

CHAPTER 9

The Students' Development of Understanding

Introduction

The learning outcomes identified for the topic were defined as a set of eight propositions:

1. If components have not been connected in a complete circuit there is no electric current in any component.
2. The amount of electric current in any part of a circuit will be the same.
3. Joins in a circuit consisting of wires, batteries and globes need to be at specific points on the batteries and globes to result in a working circuit.
4. When a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery.
5. Electric current travels in one direction through a circuit.
6. Some materials allow electricity to flow through them.
- 7a. When several batteries are connected in series, current flow will be greater than with a single battery
- 7b. If the total voltage of the batteries is greater than the voltage rating of the globe, the globe may blow; if it is less the globe will be very dim.
- 7c. When several globes are connected in series the voltage available is divided amongst the globes and the globes appear dimmer than if connected in parallel.
- 8a. When several batteries are connected in parallel, the current flow is the same as that for a single battery and the current will operate for longer than when the batteries are connected in series.
- 8b. When several globes are connected in parallel the voltage is applied equally to all the globes and they appear brighter than if connected in series.

The pencil and paper pre and posttest instrument was constructed to assess students' understanding of the propositions before and after the unit of work with the Focus Groups also participating in pre and post interviews. For each question, the students scored one mark if they made a correct, initial choice of answer. The explanation was then examined and, where the student offered an explanation that was close to a scientific response, they were given three marks. If the response demonstrated some understanding two marks were given and if the understanding was quite limited,

but there were indications of a scientific view, one mark was given. Where a student had just rephrased the question, had offered an explanation that was not understandable or the answer did not indicate any scientific understanding, no marks were given. The scores attained by each class and Focus Group are reported and the changes in understanding for each proposition discussed. The performance of the three classes is then compared and the findings related to assertions that have already been generated with some new assertions also produced.

Mr Avery’s Class

Pre and Posttest Results for the Whole Class

Twenty-five of the 28 students in the class completed both the pre and posttests. This class showed an improvement in understanding of all propositions and the mean test score increased from 7.56 on the pretest to 22.00 on the posttest, out of a maximum possible score of 59. The improvement in understanding of specific propositions varied with some showing a substantial improvement. There was a marked improvement in students’ understandings of a circuit (Propositions 1, 2 and 3). The students demonstrated a much improved understanding of where the joins needed to be in a circuit (Proposition 3) and that components not in a circuit do not have an electric current (Proposition 1). However, Proposition 2 (the amount of electric current in any part of a circuit is the same) was less well understood. Electric current travels in one direction through a circuit (Proposition 5) showed a substantial improvement.

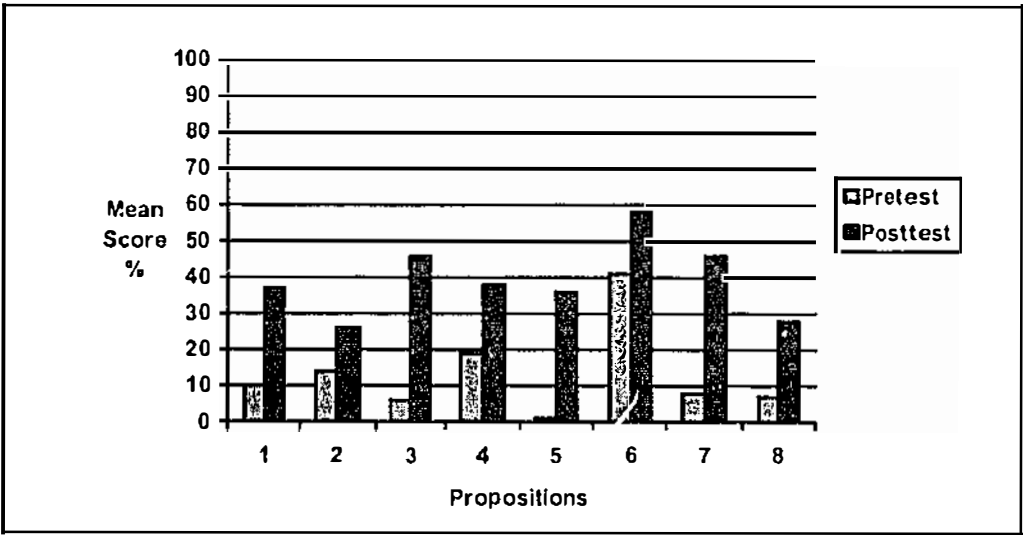


Figure 9.1. Graph showing class mean percentage scores on pre and posttests by proposition

Another area with improved scores was that of the effect of batteries in series on globes (Proposition 7), although the understanding of the differing effects of batteries in series and parallel was less well understood. The remaining propositions all showed a modest improvement. For all of the propositions the pretest scores were low and there was ample scope for improvement (Figure 9.1).

Pre and Posttest Results for the Focus Group

The Focus Group students demonstrated varying levels of understanding in the electricity pretest with Ann gaining the highest score in the class, 19 from a maximum score of 59; and Pat scoring equal lowest in the class with a score of three. All students showed an improvement in the posttest with Sue showing a substantial increase. Pat and Bob who started with low scores both showed a reasonable improvement; and Ann, who had a comparatively high pretest score, and Jon showed the least improvement although it was still reasonable (Figure 9.2).

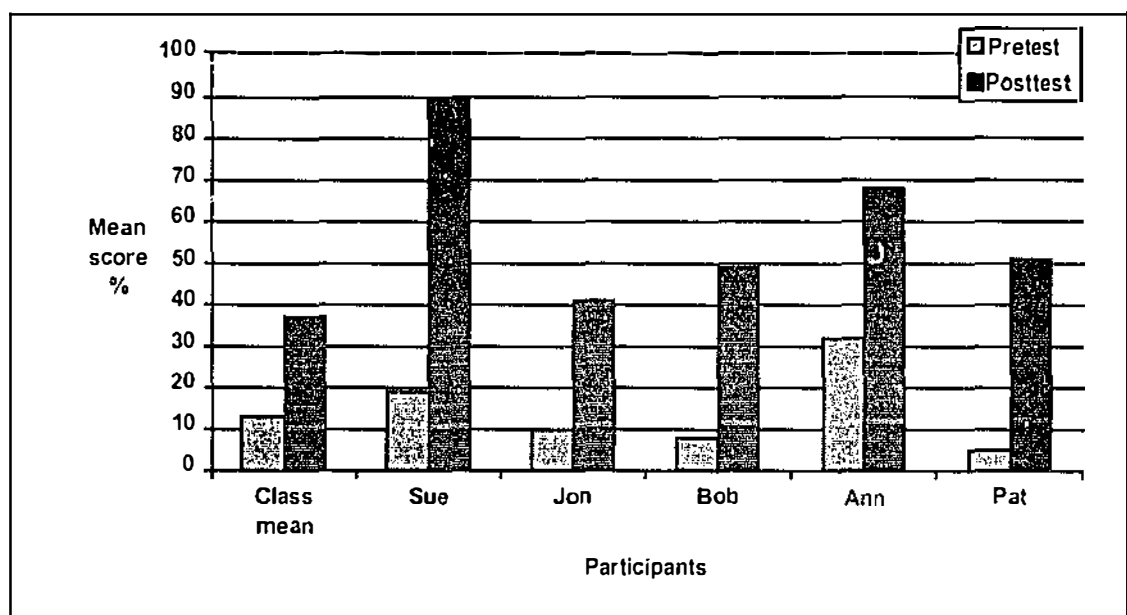


Figure 9.2. Graph showing Focus Group members' percentage scores on pre and post tests by proposition

However, in any topic taught it is difficult to ascertain how much learning has occurred in informal settings outside the classroom. Sue indicated that she had been questioning her father about one aspect of the topic and Ann frequently spoke about an uncle who worked for a firm that sold electronic equipment and may have had access to extra information from that source. Ann also discussed an electronics kit belonging to her brother that she was able to use although there is no indication of how much it was used. Jon indicated that he also had one of these kits. It is, therefore, not possible to assume that all understandings developed came from classroom interactions.

All of the Focus Group members showed a greater improvement between the pre and posttest than the mean whole class improvement in total test score.

Whole Class Conceptual Changes Between Pre and Posttests by Proposition

Proposition 1: If components have not been connected in a complete circuit there is no electric current in any component.

Student understandings of Proposition 1 were assessed by Test Questions 1, 2 and 3.

Table 9.1
Changes Between Pre and Posttests in Student Conceptions of Flow of Electrical Current in Components not in a Circuit (n = 25).

Change	Q 1	Q 2	Q 3
Retained scientific choice	14	2	2
Changed from alternative framework to scientific choice	5	11	6
Changed from no response to scientific choice	0	0	3
Total students retaining or changing to a scientific choice	19(76%)	13(52%)	11(44%)
Retained same alternative framework	0	5	5
Changed from scientific choice to alternative framework	3	0	2
Changed from one alternative framework to another	3	4	4
Changed from no response to alternative framework	0	2	3
Total students retaining or changing to an alternative framework	6(24%)	11(44%)	14(56%)
Retained no response or informal response	0	1	0
Changed from scientific choice to no response or informal response	0	0	0
Changed from alternative framework to no response or informal response	0	0	0
Total students who retained or changed to no response or informal response	0	1(4%)	0

Question 1 asked students if there was any electric current in a battery with nothing connected to it. In the posttest 19 students made the correct choice, although three students changed from a scientific view to an alternative framework. Question 2 asked if there was any electric current in a battery with wires attached that were not connected into a circuit and Question 3 asked if there was any electric current in the wires in the same situation. Both questions showed an increase the number of students making a scientific choice, although there was still a large group who had a non-scientific understandings (Table 9.1), with many of these considering that once wires were

attached to the battery there was an electric current. Six students who made an incorrect choice did not offer an understandable explanation.

The level of explanation provided by the students in the posttests showed some improvement, particularly for Question 1, with the class mean for the proposition only increasing from 1.2 to 4.4 where the total possible score was 12.

Proposition 2: The amount of electric current in any part of a circuit will be the same.

Students’ understanding of this proposition was assessed by Test Questions 5 and 10.

Table 9.2
Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 25)

Change	Q 5	Q 10
Retained scientific choice	6	2
Changed from alternative framework to scientific choice	8	9
Changed from no response to scientific choice	0	1
Total students retaining or changing to a scientific choice	14(56%)	12(48%)
Retained same alternative framework	3	1
Changed from scientific choice to alternative framework	2	3
Changed from one alternative framework to another	4	6
Changed from no response to alternative framework	1	1
Total students retaining or changing to an alternative framework	10(40%)	11(44%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	1	1
Changed from alternative framework to no response or informal response	0	1
Total students who retained or changed to no response or informal response	1(4%)	2(8%)

When responding to Question 5, which asked students to decide how much electric current was in each of three batteries in a torch, 14 students made a scientific choice on the posttest (Table 9.2) although eight of these responses did not have adequate explanations which would indicate that the concept was not well understood:

- IF4

All batteries do have the same current
- IM13

They would all have the same amount of electricity otherwise it would go bright, dimmer, bright

Three students offered idiosyncratic explanations, three made an incorrect choice but did not offer understandable explanations and four felt that the current built up as it passed from battery to battery resulting in the battery closest to the globe having the most energy. The posttest responses to Question 10, which asked students to decide how much electric current was in each of the wires in a simple circuit, showed 12 students making a scientific choice (Table 9.2), although five of these did not offer adequate explanations and a further four offered very limited explanations:

1M14 The same amount of current goes through the wires

1F26 It goes around in circles

Six students offered idiosyncratic explanations, two considered the electric current was used up in the globe and the remaining three each gave differing explanations.

The class mean increased from 1.12 to 2.08 out of a possible score of eight indicating a lack of understanding by many students.

Proposition 3: Joins in a circuit consisting of wires, batteries and globes need to be at specific points on the batteries and globes to result in a working circuit.

Students' understanding of this proposition was assessed by Test Questions 7a and 7b which asked them to identify circuits that were joined correctly and would allow the globe to light. Eighteen students demonstrated a scientific understanding in the posttest, with eight offering reasonable explanations and the remaining 10 showing limited but developing understanding (Table 9.3).

Three of the students with alternative frameworks did not consider that, when the globe was connected directly to the positive terminal of the battery, the globe would work.

The class mean increased from 0.44 to 3.24 out of a possible score of seven indicating some improvement in understanding.

Table 9.3

Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 25)

Change	Q 7a	Q 7b
Retained scientific choice	4	3
Changed from alternative framework to scientific choice	13	14
Changed from no response to scientific choice	1	1
Total students retaining or changing to a scientific choice	18(72%)	18(72%)
Retained same alternative framework	0	1
Changed from scientific choice to alternative framework	0	0
Changed from one alternative framework to another	6	5
Changed from no response to alternative framework	0	0
Total students retaining or changing to an alternative framework	6(24%)	6(24%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	0
Changed from alternative framework to no response or informal response	1	1
Total students who retained or changed to no response or informal response	1(4%)	1(4%)

Proposition 4: When a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery.

Student understanding of this proposition was assessed by Test Questions 4 and 11. Question 4 asked whether there was any current through the three batteries in a torch, and Question 11 asked if there was any current in a battery in a simple circuit. In the pretest 20 students made the correct choice for Question 4 although their explanations were limited:

IF4 *Yes, or else the torch wouldn't work*

IM13 *Because the batteries are joined together*

On the posttest, 23 students considered there was an electric current through the batteries in a torch although the level of understanding was still poor (Table 9.4). Five students offered an explanation which indicated some scientific understanding:

IF2 *They form a circuit and the electrical current can flow from negative to positive.*

IM7 *Because the electrons are flowing through the battery*

Eight showed a developing but limited understanding and 10 students gave similar answers to the pretest examples, indicating that there must be a current because the torch was working.

Table 9.4

Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electric Circuit (n = 25)

Change	Q 4	Q 11
Retained scientific choice	20	9
Changed from a limited explanation to a richer scientific explanation	3	4
Changed from no response to scientific choice	0	2
Total students retaining or changing to a scientific choice	23(92%)	15(60%)
Retained same limited explanation	0	1
Changed from scientific choice to a limited explanation	1	1
Changed from one limited explanation to another	0	3
Changed from no response to a limited explanation	0	2
Total students retaining or changing to a limited understanding	1(4%)	7(28%)
Retained no response or informal response	0	1
Changed from scientific choice to no response or informal response	1	1
Changed from a limited explanation to no response or informal response	0	1
Total students who retained or changed to no response or informal response	1(4%)	3(12%)

N.B. None of the students had any alternative frameworks

On the pretest, nine students made the correct choice for Question 11 offering limited explanations:

1M12 If the battery had no electric current the globe wouldn't work

1F1 Because otherwise the globe wouldn't light

In the posttest, 15 students considered that the battery in a simple circuit had electric current through it (Table 9.4). Four students offered an explanation which indicated some scientific understanding:

1F2 Because it is a full circuit and the current runs through the battery

1F20 All the power is coming from and flowing through the battery

Four showed a developing but limited understanding. There was no consistency in the explanations the remaining students offered, with three not attempting an explanation.

The class mean increased from 1.52 to 3.04 out of a possible score of eight indicating some improvement in understanding. However, the different answers to similar questions in the test indicate that the understanding was limited.

Proposition 5: Electric current travels in one direction through a circuit.

The students' understanding of this proposition was assessed by Test Question 9 which asked students to show the direction of current flow on a circuit diagram.

On the posttest, responses from 13 students indicated a circuit view and that current flows from negative to positive (Table 9.5) with nine of these offering a reasonable explanation and three demonstrating some understanding. Two students responded that electric current came from both ends of the battery (bi-polar view) and one other stated it only came from one end of the battery (uni-polar view). Seven students with alternative frameworks considered that the current flowed from positive to negative, although two omitted to provide any explanations. The remaining students' explanations were of a low level usually just stating that the current flowed from positive to negative. However, the responses indicate that most students had adopted a circuit view of electric current flow.

Table 9.5
Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 25)

Change	Q 9
Retained scientific choice	0 ^a
Changed from alternative framework to scientific choice	9
Changed from no response to scientific choice	4
Total students retaining or changing to a scientific choice	13(52%)
Retained same alternative framework	2
Changed from scientific choice to alternative framework	0 ^a
Changed from one alternative framework to another	4
Changed from no response to alternative framework	4
Total students retaining or changing to an alternative framework	10(40%)
Retained no response or informal response	1
Changed from scientific choice to no response or informal response	N/A
Changed from alternative framework to no response or informal response	1
Total students who retained or changed to no response or informal response	2(8%)

Note: ^a No student gave a scientific answer on the pretest.

The class mean increased from 0.04 to 1.44 out of a possible score of four indicating that, although there was an improvement, the understanding was still limited.

Proposition 6: Some materials allow electricity to flow through them.

Understanding of this proposition was assessed by Test Question 8 which asked students to select the working circuit out of one containing a conductor and one with an insulator. In the posttest all the students made a scientific choice (Table 9.6) although the level of explanation was not very high:

- IM7 A will not light because it has some wood joining to the wire. B will light up because it has a nail joining on*
- IM24 Electricity circulates through metal easier*

The class mean increased from 1.64 to 2.32 out of a possible score of four indicating that there was some improvement in understanding.

Table 9.6
Changes Between Pre and Posttests in Student Conceptions of Materials that Will Allow the Flow of Electric Current (n = 25)

Change	Q 8
Retained scientific choice	19
Changed from alternative framework to scientific choice	1
Changed from no response to scientific choice	5
Total students retaining or changing to a scientific choice	25(100%)
Retained same alternative framework	0
Changed from scientific choice to alternative framework	0
Changed from one alternative framework to another	0
Changed from no response to alternative framework	0
Total students retaining or changing to an alternative framework	0
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	0
Changed from alternative framework to no response or informal response	0
Total students who retained or changed to no response or informal response	0

Proposition 7a: When several batteries are connected in series, current flow will be greater than with a single battery.

Proposition 7h: If the total voltage of the batteries is greater than the voltage rating of the globe, the globe may blow; if it is less the globe will be very dim.

Proposition 7c: When several globes are connected in series the voltage available is divided amongst the globes and the globes appear dimmer than if connected in parallel.

This proposition was assessed by Test Questions 6a and 6b, which asked what would happen if a 1.3 volt or a 6 volt globe was put in a torch that normally has a 4.5 volt globe, and Question 12, which compared the brightness of a globe when two batteries were connected in series or parallel. Nineteen students responded correctly to Question 6a (Table 9.7), with 16 offering reasonable explanations:

1M12 It would blow because the power is too much for the globe to handle

1F18 The globe would blow because there is too much electricity going through the globe so it will blow

Twenty students responded correctly to Question 6b (Table 9.7) again with a high number (16) of good explanations:

1M23 It would not be as bright - not enough electricity

1M12 It would go dull because there isn't enough energy for the globe to work

The students who had alternative frameworks still considered that a 1.5 volt globe would not be as bright when put in the torch and that the 6 volt globe would be brighter.

The responses to Question 12 (Table 9.7) indicated that the difference between batteries in series and parallel was not as well understood with only 11 students making the correct choice and with eight giving inadequate explanations.

1F1 Because we tried it in class

1M9 Because the batteries help each other out

Of the 13 students with alternative frameworks, three held idiosyncratic, non-scientific understandings. A further four students considered that a parallel circuit would have a brighter globe than a series circuit. There was no consistency in the remaining responses.

Table 9.7
Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Series (n = 25)

Change	Q 6a	Q 6b	Q 12
Retained scientific choice	3	4	5
Changed from alternative framework to scientific choice	14	14	5
Changed from no response to scientific choice	2	2	1
Total students retaining or changing to a scientific choice	19(76%)	20(80%)	11(44%)
Retained same alternative framework	2	1	4
Changed from scientific choice to alternative framework	0	0	3
Changed from one alternative framework to another	3	1	3
Changed from no response to alternative framework	0	2	3
Total students retaining or changing to an alternative framework	5(20%)	4(16%)	13(52%)
Retained no response or informal response	0	0	1
Changed from scientific choice to no response or informal response	0	0	0
Changed from alternative framework to no response or informal response	0	0	0
Total students who retained or changed to no response or informal response	0	0	1(4%)

The class mean increased from 0.92 to 5.48 out of a possible score of 12, demonstrating a reasonable improvement in understanding. However, this was mainly related to the relationship between globe and battery voltages.

Proposition 8a. When several batteries are connected in parallel, the current flow is the same as that for a single battery and the current will operate for longer than when the batteries are connected in series.

Proposition 8b. When several globes are connected in parallel the voltage is applied equally to all the globes and they appear brighter than if connected in series.

Test Question 13 assessed students’ understanding of circuits that contained batteries in parallel and asked whether a circuit with two batteries in series or two batteries in parallel would allow the globe to shine for the longer time.

Fourteen students responded correctly in the posttest (Table 9.8) although the understanding demonstrated in the explanations was poor:

1F1 It has more backup

A high proportion of students, five, made either no response or a response that was not understandable. The six students with alternative frameworks showed no pattern in their responses.

Table 9.8
Changes Between Pre and Posttests in Student Conceptions of the Effects Connecting Batteries in Parallel (n = 25)

Change	Q 13
Retained scientific choice	2
Changed from alternative framework to scientific choice	6
Changed from no response to scientific choice	6
Total students retaining or changing to a scientific choice	14(56%)
Retained same alternative framework	2
Changed from scientific choice to alternative framework	2
Changed from one alternative framework to another	1
Changed from no response to alternative framework	1
Total students retaining or changing to an alternative framework	6(24%)
Retained no response or informal response	4
Changed from scientific choice to no response or informal response	1
Changed from alternative framework to no response or informal response	0
Total students who retained or changed to no response or informal response	5(20%)

The class mean increased from 0.28 to 1.12 out of a possible score of four indicating some improvement in understanding although the score was still very low.

Ms Brown’s Class

Pre and Posttest Results for the Whole Class

All the students in the class completed the pre and posttest. This class showed an improvement in understanding of all propositions and the mean test score increased from 11 on the pretest to 20.81 on the posttest, out of a maximum possible score of 59. The improvement of understanding of propositions varied with the least improved understanding being for Proposition 5, electric current travels in one direction through a circuit, and Proposition 2, the amount of electric current in any part of a circuit is the same. The students improved their understanding of Proposition 1, components need to be in a complete circuit and there was some improvement in their understanding of where joins need to be in a circuit (Proposition 3).

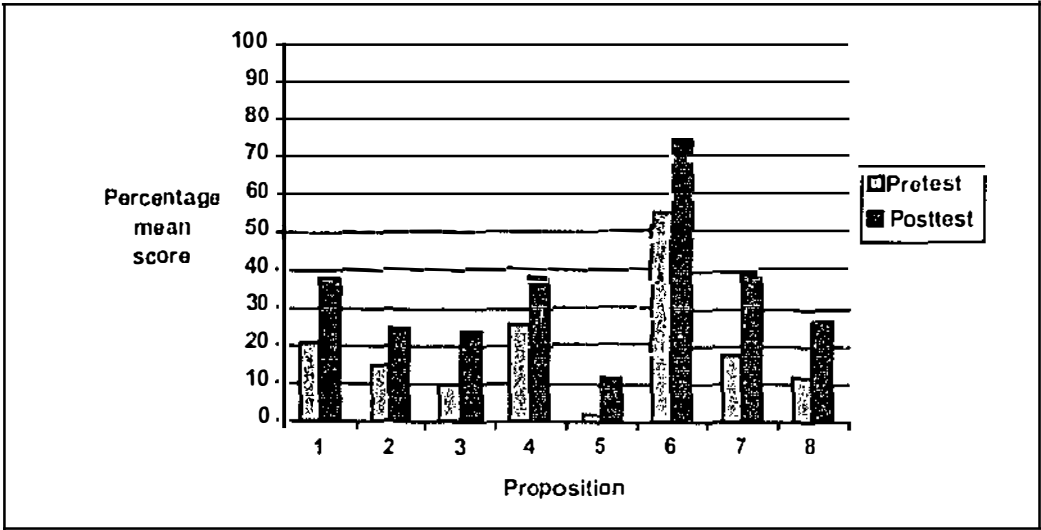


Figure 9.3. Graph showing class mean percentage scores on pre and posttests by proposition

The students demonstrated a substantial improvement in their understandings of series circuits (Proposition 7) with slightly less improvement in their understanding of Proposition 5, materials that would allow a flow of electric current and of Proposition 8, parallel circuits (Figure 9.3).

Pre and Posttest Results for the Focus Group

The Focus Group students demonstrated varying levels of understanding in the electricity pretest with Neil gaining the second highest score in the class, 20 from a maximum score of 59; and Tina scoring lowest in the class with a score of two.

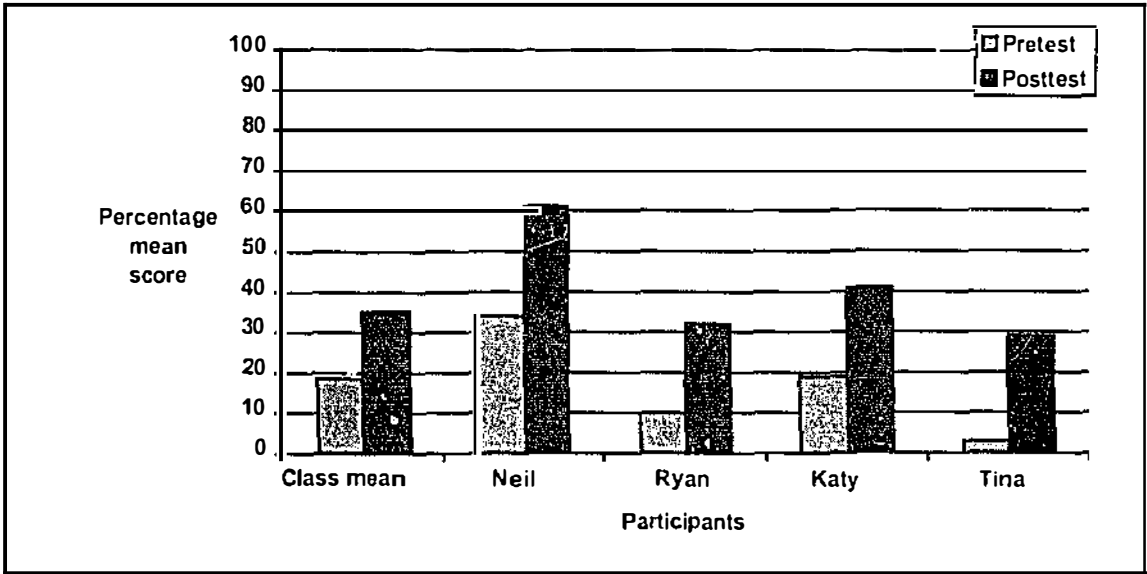


Figure 9.4. Graph showing Focus Group members' percentage scores on pre and posttests by proposition

All students showed an improvement in the posttest with the gain in scores being higher than that of the class mean. Neil and Tina had a slightly higher increase in scores than Ryan and Katy (Figure 9.4).

Whole Class Conceptual Changes between Pre and Posttests by Proposition

Proposition 1: If components have not been connected in a complete circuit there is no electric current in any component.

Students’ understanding of Proposition 1 was assessed by Test Questions 1, 2 and 3 (Table 9.9).

Table 9.9.
Changes Between Pre and Posttests in Students Conceptions of Flow of Electrical Current in Components Not in a Circuit (n = 32)

Change	Q 1	Q 2	Q 3
Retained scientific choice	14	6	6
Changed from alternative framework to scientific choice	7	8	6
Changed from no response to scientific choice	2	2	2
Total students retaining or changing to a scientific choice	23(72%)	16(50%)	14(44%)
Retained same alternative framework	2	4	5
Changed from scientific choice to alternative framework	1	4	6
Changed from one alternative framework to another	1	4	7
Changed from no response to alternative framework	2	3	0
Total students retaining or changing to an alternative framework	6(19%)	15(47%)	18(56%)
Retained no response or informal response	1	1	0
Changed from scientific choice to no response or informal response	1	0	0
Changed from alternative framework to no response or informal response	1	0	0
Total students who retained or changed to no response or informal response	3(9%)	1(3%)	0

Question 1 asked students if there was any electric current in a battery with nothing connected to it. In the posttest 23 students made the correct choice, with one student changing from a scientific view to an alternative framework. Question 2 asked if there was any electric current in a battery with wires attached that were not connected into a circuit and Question 3 asked if there was any electric current in the wires in the same situation. Both questions showed an increase in the number of students making a scientific choice, although there were still many who had a non-scientific conception,

with most of these considering that once wires were attached to the battery there was an electric current (Table 9.9).

However, the level of explanation provided by the students did not improve substantially with the class mean for the proposition only increasing from 2.5 to 4.6 of a total possible score of 12.

Proposition 2: The amount of electric current in any part of a circuit will be the same.

Students' understanding of this proposition was assessed by Test Questions 5 and 10. When responding to Question 5 in the posttest, which asked students to decide how much electric current was in each of three batteries in a torch, 16 students made a scientific choice (Table 9.10) although the explanations were generally of a low level indicating poor understanding of the concept:

2M37 *It will work best because all of the batteries are the same*
1F57 *Because the electricity goes until it runs out*

Table 9.10
Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 32)

Change	Q 5	Q 10
Retained scientific choice	8	7
Changed from an alternative framework to a scientific choice	8	7
Changed from no response to scientific choice	0	1
Total students retaining or changing to a scientific choice	16(50%)	15(47%)
Retained same alternative framework	9	4
Changed from scientific choice to an alternative framework	3	5
Changed from one alternative framework to another	3	6
Changed from no response to alternative framework	1	1
Total students retaining or changing to an alternative framework	16(50%)	16(50%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	1
Changed from an alternative framework to no response or informal response	0	0
Total students who retained or changed to no response or informal response	0	1(3%)

Most students with alternative frameworks considered that the electric current built up as it passed through the torch with one of the end batteries therefore having more current.

The responses to Question 10 in the posttest, which asked students to decide how much electric current was in each of the wires in a simple circuit, showed 15 students making a scientific choice (Table 9.10), with six of these offering reasonable explanations:

2M43 *Because the electricity flows evenly in the battery, wire and globes*

2F50 *Because the electric current goes round in a circle to the light and back to the battery*

A further five of these did not offer adequate explanations with another four offering very limited explanations.

There was no consistency in the explanations offered where students had alternative frameworks.

The class mean increased from 1.16 to 2.0 out of a possible score of eight indicating a lack of understanding by many students.

Proposition 3: Joins in a circuit consisting of wires, batteries and globes need to be at specific points on the batteries and globes to result in a working circuit.

Students' understanding of this proposition was assessed by Test Questions 7a and 7b which asked them to identify circuits that were joined correctly and would allow the globe to light. Nine students demonstrated a scientific understanding in the posttest (Table 9.11), with six offering reasonable explanations and two others showing a limited but developing understanding.

Sixteen of the students with alternative frameworks considered that the connections to the globe could be anywhere on the globe. During the lesson which considered the connections in a circuit, Ms Brown did not refer to the globe joins. Three other students considered that a globe attached directly to the battery would not work

The class mean increased from 0.72 to 1.66 out of a possible score of seven demonstrating the limited understanding held by most students.

Table 9.11

Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 32)

Change	Q 7a	Q 7b
Retained scientific choice	3	3
Changed from alternative framework to scientific choice	6	6
Changed from no response to scientific choice	0	0
Total students retaining or changing to a scientific choice	9(28%)	9(28%)
Retained same alternative framework	6	6
Changed from scientific choice to alternative framework	2	2
Changed from one alternative framework to another	14	14
Changed from no response to alternative framework	0	0
Total students retaining or changing to an alternative framework	22(69%)	22(69%)
Retained no response or informal response	1	1
Changed from scientific choice to no response or informal response	0	0
Changed from alternative framework to no response or informal response	0	0
Total students who retained or changed to no response or informal response	1(3%)	1(3%)

Proposition 4: When a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery.

Students' understanding of this proposition was assessed by Test Questions 4 and 11. Question 4 asked whether there was any current through the three batteries in a torch, and Question 11 asked if there was any current in a battery in a simple circuit. In the pretest all 32 students made the correct choice for Question 4 although all the explanations were limited:

2M38 *Because the batteries are turned on and making something work*

2F49 *There has to be for the light to shine*

On the posttest, the students still all made the scientific choice (Table 9.12).

Many explanations were still limited and no students offered explanations which indicated a scientific understanding, although 13 demonstrated a limited but developing understanding:

2M35 *It is running from the first battery to the second to the third and into the globe to make it work*

2F40 *The electric current is passing from + to - to + to - to +*

A further 12 students gave similar answers to the pretest examples, indicating that there must be a current because the torch was working.

On the pretest, 15 students made the correct choice for Question 11 offering limited explanations:

- 1M12

If the battery had no electric current the globe wouldn't work
- 2M37

Because if you don't have an electric current in the battery the light won't go

In the posttest, 25 students considered that the battery in a simple circuit had electric current through it (Table 9.12). Five students offered an explanation which indicated some scientific understanding:

- 2F40

Because the electric current passes through that to pick up the energy
- 2M52

The current flows through the wires, back to the battery and flows straight through and out again

Table 9.12
Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electrical Circuit (n = 32)

Change	Q 4	Q 11
Retained scientific choice	32	15
Changed from a limited explanation to a scientific choice	0	6
Changed from no response to scientific choice	0	4
Total students retaining or changing to a scientific choice	32(100%)	25(78%)
Retained same limited explanation	0	0
Changed from scientific choice to a limited explanation	0	3
Changed from one limited explanation to another	0	1
Changed from no response to a limited explanation	0	3
Total students retaining or changing to a limited explanation	0	7(22%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	0
Changed from a limited explanation to no response or informal response	0	0
Total students who retained or changed to no response or informal response	0	0

N.B. None of the students had any alternative frameworks for Question 4

Fifteen students showed a developing but limited understanding with 10 of these offering similar answers to the examples given for the pretest. There was no consistency in the explanations provided by the students with alternative frameworks.

The class mean increased from 2.06 to 3.06 out of a possible score of eight indicating a small improvement in understanding. The differences in answers to two similar questions indicate that the understanding was limited.

Proposition 5: Electric current travels in one direction through a circuit.

The students' understanding of this proposition was assessed by Test Question 9 which asked students to show the direction of current flow on a circuit diagram. On the posttest, seven students indicated a circuit view and that current flows from negative to positive (Table 9.13) with three of these offering a reasonable explanation. Six students responded that electric current came from both ends of the battery (bi-polar view) and 15 students considered that the current flowed from positive to negative. However, the responses indicate that most students had adopted a circuit view of electric current flow. The explanations offered by most students with a positive to negative view of current flow generally were limited although four included the idea of a circuit.

Table 9.13
Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 32)

Change	Q 9
Retained scientific choice	0
Changed from alternative framework to scientific choice	6
Changed from no response to scientific choice	1
Total students changing to a scientific choice	7(22%)
Retained same alternative framework	8
Changed from scientific choice to alternative framework	0
Changed from one alternative framework to another	10
Changed from no response to alternative framework	3
Total students retaining or changing to an alternative framework	21(66%)
Retained no response or informal response	1
Changed from scientific choice to no response or informal response	1
Changed from alternative framework to no response or informal response	2
Total students who retained or changed to no response or informal response	4(12%)

The class mean increased from 0.06 to 0.47 out of a possible score of four indicating that the improvement in understanding was very limited.

Proposition 6: Some materials allow electricity to flow through them.

Understanding of this proposition was assessed by Test Question 8 which asked students to select the working circuit out of one containing a conductor and one with an insulator.

In the posttest most students, 31, made a scientific choice (Table 9.14) showing varying levels of understanding in their explanations:

- 2M31 *Wood is an insulator*
- 2M59 *Because wood is not a good conductor while nails are ... the wood stops the circuit from being complete*

The class mean increased from 2.25 to 3.0 out of a possible score of four. Although the increase in understanding from the pre to the posttest was not large, most students had a good understanding of the proposition.

Table 9.14
Changes Between Pre and Posttests in Student Conceptions of Materials that will Allow Electric Current to Flow Through Them (n = 32)

Change	Q 8
Retained scientific choice	29
Changed from an alternative framework to a scientific choice	2
Changed from no response to scientific choice	0
Total students retaining or changing to a scientific choice	31(97%)
Retained same alternative framework	0
Changed from scientific choice to an alternative framework	0
Changed from one alternative framework to another	0
Changed from no response to alternative framework	0
Total students retaining or changing to a limited explanation	0
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	1
Changed from an alternative framework to no response or informal response	0
Total students who retained or changed to no response or informal response	1(3%)

Proposition 7a: When several batteries are connected in series, current flow will be greater than with a single battery.

Proposition 7b: If the total voltage of the batteries is greater than the voltage rating of the globe, the globe may blow; if it is less the globe will be very dim.

Proposition 7c: When several globes are connected in series the voltage available is divided amongst the globes and the globes appear dimmer than if connected in parallel.

This proposition was assessed by Test Questions 6a and 6b, which asked what would happen if a 1.3 volt or a 6 volt globe was put in a torch which normally had a 4.5 volt globe, and Question 12, which compared the brightness of a globe when two batteries were connected in series and parallel. Twenty-two students responded correctly to Question 6a (Table 9.15), with 13 offering reasonable explanations:

- 2M38 *Too much energy is going to the globe and the globe can't handle it*
2F40 *It can only take 1.3 volts and if the batteries are giving 4.5 volts it will blow*

Twenty-six students responded correctly to Question 6b (Table 9.15) with 11 students offering reasonable explanations:

- 2F47 *It would be more dimmer because there's not enough electric current for the globe*
2M59 *The light would glow dimly because the batteries only give out 4.5 volts and the 6 volt globe needs 6 volts to glow*

Most students who had alternative frameworks still considered that a 1.5 volt globe would not be as bright with three batteries and that the 6 volt globe would be brighter.

The responses to Question 12 (Table 9.15) indicated that the understanding of the difference between batteries in series and parallel was not as well understood. Sixteen students made the correct choice but only two gave adequate explanations with four having explanations that did not agree with their choice of circuit, and the remainder offering a variety of answers:

- 2F39 *Because it has to be different wires for the battery tops*
2F49 *When we tried it it worked brighter*

Table 9.15

Changes Between Pre and Posttests in Student Conceptions of the Effect of Connecting Batteries in Series (n = 32)

Change	Q 6a	Q 6b	Q 12
Retained scientific choice	8	12	8
Changed from alternative framework to scientific choice	14	14	8
Changed from no response to scientific choice	0	0	0
Total students retaining or changing to a scientific choice	22(69%)	26(81%)	16(50%)
Retained same alternative framework	3	1	1
Changed from scientific choice to alternative framework	1	0	4
Changed from one alternative framework to another	4	2	8
Changed from no response to alternative framework	1	1	1
Total students retaining or changing to an alternative framework	9(28%)	4(12%)	14(44%)
Retained no response or informal response	0	0	0
Changed from scientific choice to no response or informal response	0	1	0
Changed from alternative framework to no response or informal response	1	1	2
Total students who retained or changed to no response or informal response	1(3%)	2(6%)	2(6%)

Of the 14 students with alternative frameworks, five held idiosyncratic, non-scientific understandings. A further two students considered that a parallel circuit would have a brighter globe than a series circuit. There was no consistency in the remaining responses.

The class mean increased from 2.12 to 4.81 out of a possible score of 12. The improvement in understanding was mainly of the relationship between globe and battery voltages.

Proposition 8a. When several batteries are connected in parallel, the current flow is the same as that for a single battery and the current will operate for longer than when the batteries are connected in series.

Proposition 8b. When several globes are connected in parallel the voltage is applied equally to all the globes and they appear brighter than if connected in series.

Test Question 13 assessed students' understanding of circuits that contained batteries in parallel and asked whether a circuit with two batteries in series or two batteries in parallel would allow the globe to shine for the longer time.

Table 9.16

Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Parallel (n = 32)

Change	Q 13
Retained scientific choice	12
Changed from an alternative framework to a scientific choice	12
Changed from no response to scientific choice	1
Total students retaining or changing to a scientific choice	25(78%)
Retained same alternative framework	2
Changed from scientific choice to an alternative framework	2
Changed from one alternative framework to another	1
Changed from no response to alternative framework	1
Total students retaining or changing to a limited explanation	6(19%)
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	0
Changed from an alternative framework to no response or informal response	1
Total students who retained or changed to no response or informal response	1(3%)

Twenty-five students responded correctly in the posttest (Table 9.16) although the understanding demonstrated in the explanations was poor:

2M31 *Because it is a parallel circuit*

2F49 *The power is used more economically*

Of the six students with alternative frameworks, two students chose the series circuit and stated that it was connected correctly and the remaining four showed no

pattern in their responses. The class mean increased from 0.47 to 1.09 out of a possible score of four indicating little improvement in understanding..

Mr Carter's Class

Pre and Posttest Results for the Whole Class

All the 30 students in the class completed the pre and posttests. This class showed an improvement in understanding of all propositions and the mean test score increased from 12.4 on the pretest to 24.8 on the posttest, out of a maximum score of 59.

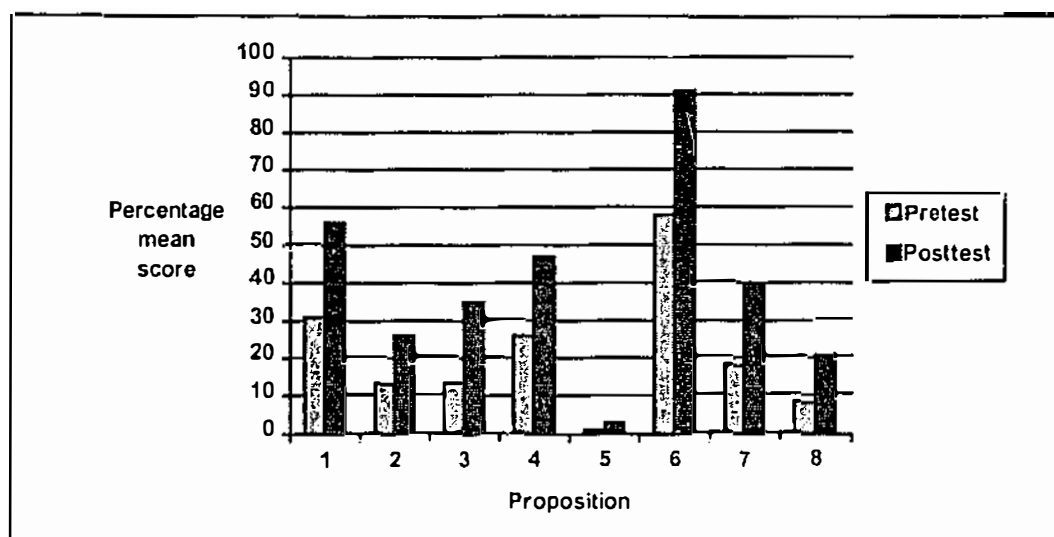


Figure 9.5. Graph showing class mean percentage scores on pre and posttest by proposition

However, the improvement in score for Proposition 5 referring to the direction of current flow, was minimal. This was a proposition where there was minimal knowledge at the pretest stage and there was opportunity for improvement. There was a marked improvement in the students' understanding of a circuit (Propositions 1, 2 and 3). The students demonstrated a much improved understanding of where the joins needed to be in a circuit (Proposition 3) and that components not in a circuit did not have an electric current (Proposition 1). Their understanding that the amount of current anywhere in a circuit is the same also showed some improvement (Proposition 2). They demonstrated an improved understanding of Proposition 4, that there is an electric current through all parts of a circuit, and of Proposition 6, materials that would allow the flow of electric current. They also showed a better understanding of series circuits although there was a much smaller improvement in their understanding of parallel circuits (Figure 9.5).

Pre and Posttest Results for the Focus group

The students showed varying levels of understanding in the pretest. Out of a class of 30 students, Colin was eighth in the class with a score of 16 from a maximum score of 59; and Linda was twenty-ninth with a score of three.

All students showed an improvement from the pretest to the posttest with Colin showing the least improvement from 16 to 21, and Helen showing the most, from seven to 27. She was the only student in the group to score above the class mean (Figure 9.6). However, some of the Focus Group members' understandings were unstable, and changed either between the posttest and the interview or during the interview.

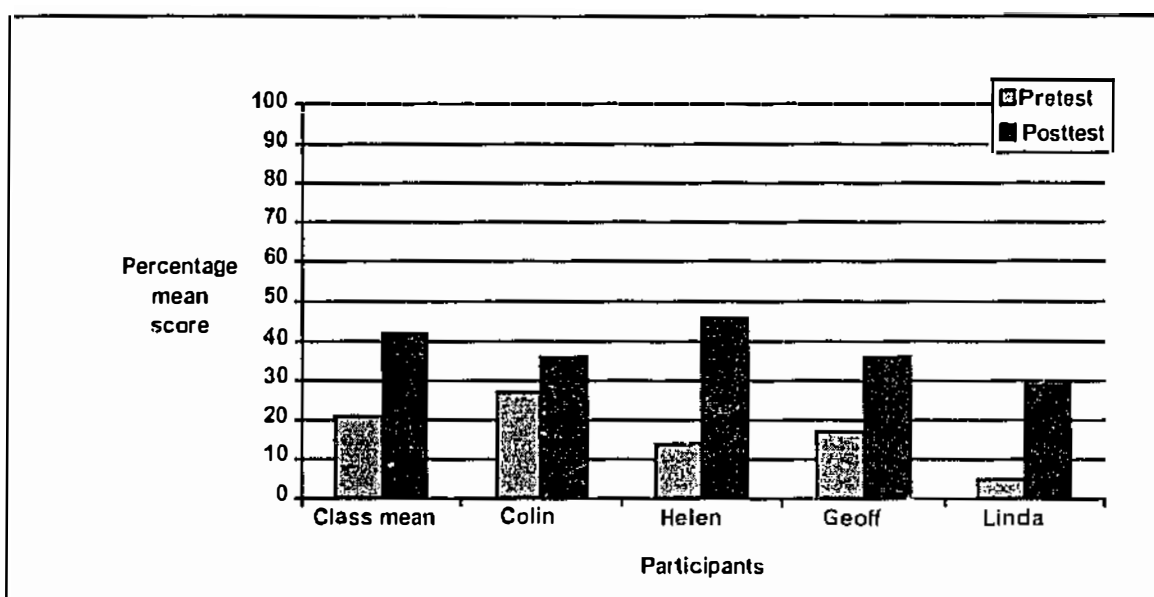


Figure 9.6. Graph showing Focus Group members' percentage scores on pre and posttests by proposition

Whole Class Conceptual Changes between Pre and Posttests by Proposition

Proposition 1: If components have not been connected in a complete circuit there is no electric current in any component.

Student conceptions of Proposition 1 were assessed by Test Questions 1, 2 and 3. Question 1 asked students if there was any electric current in a battery with nothing connected to it. In the posttest 28 students made the correct choice, with one student changing from a scientific view to an alternative framework. Question 2 asked if there was any electric current in a battery with wires attached that were not connected into a circuit and Question 3 asked if there was any electric current in the wires in the same situation. Both questions showed a substantial increase in the number of students making a scientific choice, with most of those making a non-scientific choice

considering that once wires were attached to the battery there was an electric current (Table 9.17).

The level of explanation provided by students demonstrated an improved understanding of the proposition and the class mean for the proposition increased from 3.7 to 6.7 out of a total possible score of 12. However, the responses from the Focus Group showed a lack of stability and may indicate that the learning was limited.

Table 9.17
Changes Between Pre and Posttests in Student Conceptions of Flow of Electrical Current in Components Not in a Circuit (n = 30).

Change	Q 1	Q 2	Q 3
Retained scientific choice	19	12	14
Changed from alternative framework to scientific choice	5	8	5
Changed from no response to scientific choice	4	2	2
Total students retaining or changing to a scientific choice	28(93%)	22(73%)	21(70%)
Retained same alternative framework	0	5	3
Changed from scientific choice to alternative framework	1	0	5
Changed from one alternative framework to another	1	0	0
Changed from no response to alternative framework	0	2	0
Total students retaining or changing to an alternative framework	2(7%)	7(23%)	8(27%)
Retained no response or informal response	0	1	0
Changed from scientific choice to no response or informal response	0	0	0
Changed from alternative framework to no response or informal response	0	0	1
Total students who retained or changed to no response or informal response	0	1(3%)	(3%)

Responses provided by the Focus Group students on the posttests and interviews showed uncertainty and inconsistency, and demonstrated little real understanding of the need for a complete circuit to allow electric current to flow (Table 9.18).

All the Focus Group students changed their answers to at least one of the questions between the posttest and the interview.

Table 9.18
A Comparison of Focus Group Student Choices for Questions 1, 2 and 3 between the Posttest and Interview

Question number	Colin		Helen		Geoff		Linda	
	Posttest	Interview	Posttest	Interview	Posttest	Interview	Posttest	Interview
1	No	No	No	No	No	Unsure	No	No
2	No	Yes	No	Yes	Yes	Yes	Yes	No
3	Yes	Yes	No	Yes	Yes	Unsure	Yes	Unsure

Proposition 2: The amount of electric current in any part of a circuit will be the same.

Students’ understanding of this proposition was assessed by Test Questions 5 and 10. When responding to Question 5, which asked students to decide how much electric current was in each of three batteries in a torch, 15 students made a scientific choice (Table 9.19) although 12 of these responses did not have adequate explanations which indicates that the concept was not well understood:

- 1F4

All batteries do have the same current
- 3F93

I think all of the batteries have the same amount or else it wouldn't work as well

Most students with alternative frameworks considered the electric current built up in the battery closest to the globe.

The responses to Question 10, which asked students to decide how much electric current was in each of the wires in a simple circuit, showed 21 students making a scientific choice (Table 9.19), although only three offered reasonable explanations. Four students who made the correct choice had a bi-polar view of current flow which would result in them making their choice for the wrong reasons. There was obviously a lack of understanding with nine of the students who made the correct choice indicating that their choice was made because they felt it was right, or that it had been shown in the class activities.

- 3F69

It explains what I think will go on
- 3M70

It has to be an even amount of electricity

The students who had alternative frameworks for this question showed no consistency in their answers.

The class mean increased from 1.07 to 2.07 out of a possible score of eight indicating a lack of understanding by many students.

Table 9.19
Changes Between Pre and Posttests in Student Conceptions of the Amount of Electric Current in Any Part of a Circuit (n = 30)

Change	Q 5	Q 10
Retained scientific choice	10	4
Changed from an alternative framework to a scientific choice	4	11
Changed from no response to scientific choice	1	6
Total students retaining or changing to a scientific choice	15(50%)	21(70%)
Retained same alternative framework	9	2
Changed from scientific choice to an alternative framework	3	2
Changed from one alternative framework to another	3	2
Changed from no response to alternative framework	0	3
Total students retaining or changing to an alternative framework	15(50%)	9(30%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	0
Changed from an alternative framework to no response or informal response	0	0
Total students who retained or changed to no response or informal response	0	0

Proposition 3: Joins in a circuit consisting of wires, batteries and globes need to be at specific points on the batteries and globes to result in a working circuit.

Students’ understanding of this proposition was assessed by Test Questions 7a and 7b which asked them to identify circuits that were joined correctly and would allow the globe to light.

Nineteen students demonstrated a scientific understanding in the posttest (Table 9.20), with 12 offering reasonable explanations and the remaining seven showing limited but developing understandings.

Six of the students with alternative frameworks considered that the connections to the globe could be anywhere on the globe, and two considered that a globe attached directly to the battery would not work.

The class mean increased from 0.9 to 2.43 out of a possible score of seven demonstrating a limited improvement in understanding.

Table 9.20

Changes Between Pre and Posttests in Student Conceptions of Complete Working Circuits: Position of Joins in a Circuit (n = 30)

Change	Q 7a	Q 7b
Retained scientific choice	5	5
Changed from alternative framework to scientific choice	13	13
Changed from no response to scientific choice	1	1
Total students retaining or changing to a scientific choice	19(63%)	19(63%)
Retained same alternative framework	5	5
Changed from scientific choice to alternative framework	1	1
Changed from one alternative framework to another	4	4
Changed from no response to alternative framework	1	1
Total students retaining or changing to an alternative framework	11(37%)	11(37%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	0
Changed from alternative framework to no response or informal response	0	0
Total students who retained or changed to no response or informal response	0	0

Proposition 4: When a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery.

Student understanding of this proposition was assessed by Test Questions 4 and 11. Question 4 asked whether there was any current through the three batteries in a torch, and Question 11 asked if there was any current in a battery in a simple circuit. In the pretest 28 students made the correct choice for Question 4 with three offering a reasonable explanation. However, the remaining explanations were limited:

2F68 *Because the globe is glowing*

3M83 *There has to get the electricity to light the globe*

On the posttest, 29 students made the scientific choice (Table 9.21). Seven students offered explanations which indicated some scientific understanding, and 10 demonstrated a limited but developing understanding:

3M65 *Because all the batteries are joined together*

3F75 *Because the negative and positive ends are touching*

A further 12 students gave similar answers to the pretest examples, indicating that there must be a current because the torch was working.

On the pretest, 12 students made the correct choice for Question 11 (Table 9.21) with two having a scientific view and the others offering limited explanations:

- 3F66

Because otherwise the globe would not light up
- 3M86

Because the light is still going

In the posttest, 24 students considered that the battery in a simple circuit had electric current through it. Six students now offered an explanation which indicated some scientific understanding:

- 2F80

Because there is a complete circuit
- 3M86

Because in a circuit the current flows from the battery, around the wires, and back through the battery

Four students showed a developing but limited understanding and six students offered similar answers to those given in the pretest. There was no consistency in the explanations offered by the remaining students.

Table 9.21
Changes Between Pre and Posttests in Student Conceptions of Current Flow in a Battery in an Electrical Circuit (n = 30)

Change	Q 4	Q 11
Retained scientific choice	28	12
Changed from a limited explanation to a scientific choice	6	5
Changed from no response to scientific choice	1	7
Total students retaining or changing to a scientific choice	29(97%)	24(80%)
Retained same limited explanation	0	2
Changed from scientific choice to a limited explanation	0	2
Changed from one limited explanation to another	0	0
Changed from no response to alternative framework	0	2
Total students retaining or changing to a limited explanation	1(3%)	6(20%)
Retained no response or informal response	0	0
Changed from scientific choice to no response or informal response	0	0
Changed from a limited explanation to no response or informal response	1	0
Total students who retained or changed to no response or informal response	0	0

N.B. None of the students had any alternative frameworks

The class mean increased from 2.07 to 3.77 out of a possible score of eight indicating a small improvement in understanding. However, several students offered differing responses to the two similar questions, which may indicate that the understanding was limited.

Proposition 5: Electric current travels in one direction through a circuit.

The students’ understanding of this proposition was assessed by Test Question 9 which asked students to show the direction of current flow on a circuit diagram. On the posttest, only three students indicated a circuit view and that current flows from negative to positive (Table 9.22) with only one of these offering a reasonable explanation. Fourteen students considered that the current flowed from positive to negative reflecting Mr Carter’s own current flow view. Three students responded that electric current came from both ends of the battery (bi-polar view). However, the responses indicate that most students had adopted a circuit view of electric current flow. The explanations offered by most students with a positive to negative view of current flow were generally limited:

- 3M67 *Electricity travels from + to –*
- 3M74 *Positive gives power negative does not*

Table 9.22
Changes Between Pre and Posttests in Student Conceptions of Direction of Current Flow in an Electric Circuit (n = 30)

Change	Q 9
Retained scientific choice	N/A
Changed from alternative framework to scientific choice	3
Changed from no response to scientific choice	0
Total students changing to a scientific choice	3(10%)
Retained same alternative framework	5
Changed from scientific choice to alternative framework	1
Changed from one alternative framework to another	14
Changed from no response to alternative fra mework	7
Total students retaining or changing to an alternative framework	27(90%)
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	N/A
Changed from alternative framework to no response or informal response	1
Total students who retained or changed to no response or informal response	1(3%)

The class mean increased from 0.03 to 0.10 out of a possible score of four indicating that there was minimal improvement in understanding.

Proposition 6: Some materials allow electricity to flow through them.

Understanding of this proposition was assessed by Test Question 8 which asked students to select the working circuit out of one containing a conductor and one with an insulator. In the posttest all students made a scientific choice (Table 9.23) showing varying levels of understanding in their explanations:

- 3F73

Because a nail is a conductor and wood is an insulator
- 3F80

Because a nail is metal and metal is a conductor so it completes the circuit

Table 9.23
Changes Between Pre and Posttests in Student Conceptions of Materials that will Allow the Flow of Electric Current (n = 30)

Change	Q 8
Retained scientific choice	27
Changed from a limited explanation to a scientific choice	0
Changed from no response to scientific choice	3
Total students retaining or changing to a scientific choice	30(100%)
Retained same limited explanation	0
Changed from scientific choice to a limited explanation	0
Changed from one limited explanation to another	0
Changed from no response to alternative framework	0
Total students retaining or changing to a limited explanation	0
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	0
Changed from a limited explanation to no response or informal response	0
Total students who retained or changed to no response or informal response	0

The class mean increased from 2.33 to 3.63 out of a possible score of four demonstrating a good understanding.

Proposition 7a: When several batteries are connected in series, current flow will be greater than with a single battery.

Proposition 7b: If the total voltage of the batteries is greater than the voltage rating of the globe, the globe may blow; if it is less the globe will be very dim.

Proposition 7c: When several globes are connected in series the voltage available is divided amongst the globes and the globes appear dimmer than if connected in parallel.

This proposition was assessed by Test Questions 6a and 6b, which asked what would happen if a 1.3 volt or a 6 volt globe was put in a torch that normally had a 4.5 volt globe, and Question 12, which compared the brightness of a globe when two batteries were connected in series and parallel. Twenty-eight students responded correctly to Question 6a (Table 9.24), with 17 offering reasonable explanations:

- 3M78 *The globe will blow. This will happen because the 1.3 isn't meant to hold that much volts*
- 3F87 *The filament in the globe will snap, blowing the globe. This will happen because there will be too much electricity for the globe which causes the filament to break*

Twenty-three students responded correctly to Question 6b (Table 9.24) with 17 students offering a reasonable explanation:

- 3F71 *The light would be dull because the globe is higher than the current and it wouldn't have enough current to keep it going*
- 3F66 *The globe would glow dimmer because there is less voltage in the batteries than the globe can take so it needs more power to light it up*

Most students who had alternative frameworks still considered that a 1.5 volt globe would not be as bright when connected to three batteries in series and that the 6 volt globe would be brighter.

The responses to Question 12 (Table 9.24) indicated that the understanding of the difference between batteries in series and parallel was not as well understood. Eight students made the correct choice with no students offering scientific explanations:

- 3F80 *Because it is a circuit that uses more power quicker*
- 3M94 *Because series circuits deliver more power*

Of the 21 students with alternative frameworks, five students made statements that did not agree with their choice of circuits; four chose the parallel circuit and said

that the connections were correct; and seven considered that a parallel circuit would have the brightest globes.

Table 9.24

Changes Between Pre and Posttests in Student Conceptions of the Effect of Connecting Batteries in Series (n = 30)

Change	Q 6a	Q 6b	Q 12
Retained scientific choice	9	10	2
Changed from alternative framework to scientific choice	18	12	2
Changed from no response to scientific choice	1	1	4
Total students retaining or changing to a scientific choice	28(93%)	23(77%)	8(27%)
Retained same alternative framework	1	3	1
Changed from scientific choice to alternative framework	0	1	4
Changed from one alternative framework to another	1	2	7
Changed from no response to alternative framework	0	0	9
Total students retaining or changing to an alternative framework	2(7%)	6(20%)	21(70%)
Retained no response or informal response	0	0	0
Changed from scientific choice to no response or informal response	0	1	1
Changed from alternative framework to no response or informal response	0	0	0
Total students who retained or changed to no response or informal response	0	1(3%)	1(3%)

The class mean increased from 2.17 to 4.83 out of a possible score of 12. The improvement in understanding was mainly of the relationship between globe and battery voltages.

Proposition 8a. When several batteries are connected in parallel, the current flow is the same as that for a single battery and the current will operate for longer than when the batteries are connected in series.

Proposition 8b. When several globes are connected in parallel the voltage is applied equally to all the globes and they appear brighter than if connected in series.

Test Question 13 examined student understanding of circuits that contained batteries in parallel and asked whether a circuit with two batteries in series or two batteries in parallel would allow the globe to shine for the longer time.

Table 9.25
Changes Between Pre and Posttests in Student Conceptions of the Effects of Connecting Batteries in Parallel (n = 30)

Change	Q 13
Retained scientific choice	6
Changed from an alternative framework to a scientific choice	6
Changed from no response to scientific choice	10
Total students retaining or changing to a scientific choice	22(73%)
Retained same alternative framework	0
Changed from scientific choice to an alternative framework	0
Changed from one alternative framework to another	2
Changed from no response to alternative framework	3
Total students retaining or changing to a limited explanation	5(17%)
Retained no response or informal response	0
Changed from scientific choice to no response or informal response	3
Changed from an alternative framework to no response or informal response	0
Total students who retained or changed to no response or informal response	3(10%)

Twenty-two students made the scientific choice in the posttest (Table 9.25) although the understanding demonstrated in the explanations was limited:

- 3F77

The circuit is better arranged
- 3M79

Because our experiment showed that the parallel circuit was the longest lasting one

Three students gave answers that were not understandable or offered no response. The five students with alternative frameworks showed no pattern in their responses.

The class mean increased from 0.3 to 0.83 out of a possible score of four indicating very little improvement in understanding.

Comparison of Classes

Whole Class Results

All the classes showed an improvement in their mean scores from the pre to the posttest with Mr Avery’s class showing the greatest increase and Ms Brown’s the least. None of the final scores were close to the maximum with Mr Carter’s class gaining the highest result at 24.5 out of a maximum possible score of 59. When the increase in scores is considered, Mr Avery’s class showed the greatest improvement, with Mr

Carter’s class showing the next greatest and Ms Brown’s class the least improvement (Figure 9.7).

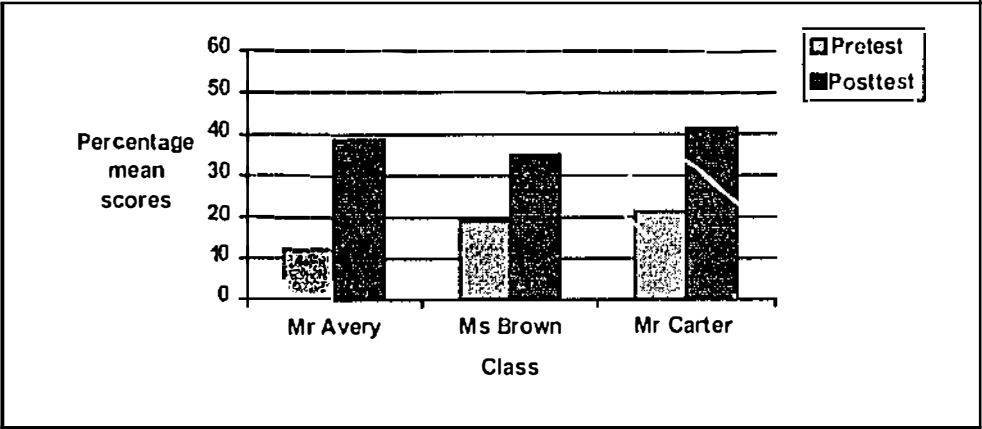


Figure 9.7: Graph showing percentage mean scores for the pre and posttests for the three classes

The increases in percentage total test mean scores between pre and posttest were 26 for Mr Avery’s class, 16 for Ms Brown’s class and 20 for Mr Carter’s class. When the mean percentage scores by proposition are compared, all classes showed some improvement on all propositions (Table 9.26). The least improvement was for Mr Carter’s class for Proposition 5, electric current travels in one direction through a circuit (2%) and Ms Brown’s class for Proposition 2, the amount of electric current in any part of a circuit will be the same (10%), and Proposition 5, electric current travels in one direction through a circuit (10%). The greatest improvement between pre and posttest scores were in Mr Avery’s class for Proposition 3, the position of joins in a circuit (40%), Proposition 7, series circuits (38%), and Proposition 5, electric current travels in one direction through a circuit (31%) and in Mr Carter’s class for Proposition 6, materials that will allow the flow of electric current (33%) (Table 9.26).

Table 9.26

Percentage Increase in Scores between Pre and Posttest for all Classes by Proposition

	Percentage increase by proposition							
	1	2	3	4	5	6	7	8
Mr Avery	27	12	40	19	31	17	38	21
Ms Brown	17	10	14	12	10	19	22	15
Mr Carter	25	13	22	21	2	33	22	13

Focus Group Results

Of the Focus Groups, Mr Avery’s group showed the most improvement with the lowest increase between pre and posttests by a member of this group being 31 % (Table 9.27). In the other classes only one student had an increase in score that was higher than the least increase in Mr Avery’s group (Tables 9.28, 9.29). The mean group increase in scores between pre and posttests was 45% for Mr Avery’s group, 24% for Ms Brown’s group and 21% for Mr Carter’s group. The Focus Group students who demonstrated a low level of knowledge on the pretest in Mr Avery’s class generally showed more substantial increases in their scores than similar students in the other two classes, although Helen, in Mr Carter’s class also demonstrated a substantial improvement. Colin, who was ranked at level 3 when the students were ranked by ability showed the least improvement, and the interview confirmed the posttest results. Helen, the other level three student made a considerable improvement although there were a few areas in which she showed uncertainty in the interview. Of the students who were considered to be the high-ability students, Sue, Bob, Ann, Neil and Geoff, Geoff showed the least improvement with all the others demonstrating a reasonable level of improvement and Sue achieving an exceptional increase (Tables 9.27, 9.28, 9.29).

Table 9.27
Increase in Percentage Total Test Scores for Focus Group Students from Mr Avery’s Class

Increase in Scores					
Sue	Jon	Bob	Ann	Pat	Focus Group mean
71	31	41	36	46	45

Table 9.28
Increase in Percentage Total Test Scores for Focus Group Students from Ms Brown’s Class

Increase in Scores				
Neil	Ryan	Katy	Tina	Focus Group mean
27	22	22	26	24

Table 9.29
 Increase in Percentage Total Test Scores for Focus Group Students from Mr Carter's Class

Increase in Scores				
Colin	Helen	Geoff	Linda	Focus Group mean
9	32	19	24	21

Discussion

Previous chapters have indicated the range of teaching and learning styles in the classrooms. The results reflect the effects of some of these styles.

The ability to present the information in many ways and extend the teaching is important (Carlsen, 1991b; Sanders et al., 1993; Wilson et al., 1987). Mr Avery was the teacher with the most knowledge about the topic and about alternative frameworks. He conducted interesting discussions which maintained the interest of the students and, because of his background knowledge, was able to use a range of strategies and demonstrations to illustrate and explain phenomena. Caravita and Halldén (1994) and Driver and Oldham (1986) suggest that a supportive classroom environment is important and Mr Avery’s friendly supportive attitude encouraged the students to become engaged in learning and the students were willing to question things with which they disagreed or that they did not understand. The students were willing to explain their answers and this helped Mr Avery recognise their understandings and, where necessary, address them. The students in Mr Avery’s class showed the greatest improvement in understanding of the classes for most propositions.

Assertion 9/86

Where teachers are knowledgeable and use a wide variety of methods to illustrate and explain phenomena, with students engaged in discussion and constructing ideas, the students have more opportunities for learning and are more likely to reach scientifically acceptable understandings.

Generally Mr Avery covered all the concepts in the curriculum materials, adapting them to fit his teaching. However, he omitted much of the relevant teaching for Proposition 2, the amount of electric current in any part of a circuit will be the same, and this is reflected in the limited improvement in scores that the students showed on this proposition. Ms Brown omitted parts of the curriculum related to joins in a circuit and Mr Carter changed the information available when teaching direction of current flow. Smith and Neale (1989) suggest that inappropriate teacher changes to curriculum materials will limit the learning that will occur.

Assertion 9/87

Where teachers omit parts of the curriculum or do not use the supplied materials, students may not be given the opportunity to develop scientifically acceptable understandings.

Reviews allow the students an opportunity to check their understandings and are usually used by the teacher to ascertain student recall of previous activities (Gage & Berliner, 1992; Swift et al. 1988). The links made during reviews are also important as students often do not connect parts of a lesson or individual lessons to each other (Tasker, 1981). Both Mr Avery and Mr Carter conducted frequent reviews and made links between and within lessons, with Mr Avery's reviews being more comprehensive than Mr Carter's. Mr Avery covered most of the focus questions from the lesson outlines in his reviews. Mr Carter, because of his emphasis on student guided reviews tended to cover the basic understandings but not the more difficult ones, although some were covered during the lessons. Ms Brown rarely conducted reviews or made links and did not refer to the focus questions in her lessons. This may have had an effect on the more limited improvement in understanding demonstrated by her students on the posttest. However, Ms Brown's teaching style and relationship with the students would also have limited opportunities for learning.

Because of Mr Avery's adaptation of the lessons, the students were given more reviews related to series and parallel circuits. Ms Brown and Mr Carter only had limited opportunities to review series circuits, during and at the end of Lesson 3 and during and at the beginning of Lesson 4. Neither teacher took effective advantage of these opportunities. The improvement in understanding of the attributes of and differences between series and parallel circuits was considerably higher in Mr Avery's class than in either of the other classes.

Assertion 9/88

Where effective reviews are not conducted it is likely that any improvement in understanding will be limited.

Linn and Burhules (1993) considered that many groups do not have good discussion skills. The Focus Group in Mr Avery's class was unusually effective as a group. They were able to discuss and work collaboratively with few problems and were consistently on-task, which gave them more opportunity to learn (Ross, 1984). All the students in this group showed substantial improvement in their understanding of the propositions. The Focus Group from Mr Carter's class was dysfunctional and was unable to work as a cooperative group. Apart from Helen, their score increases from the pre to posttest were lower than those of Mr Avery's Focus Group.

Assertion 9/89

Groups that do not have the skills to work cooperatively are less likely to improve their understanding of the concepts under investigation.

Three of the Focus Group students that did not participate noticeably in the activities and discussions, were Pat in Mr Avery's class, Tina in Ms Brown's class and Helen in Mr Carter's class. Pat and Tina's more limited participation appeared to be influenced by the group, whereas Helen's appeared to be lack of motivation, although she was generally also less engaged in the social discussion so it may also have been influenced by the group. Kempa and Ayob (1991) argued that self imposed passivity with some participation allowed students to still learn, however, they felt that where the limited participation was imposed by the group the student was less likely to learn. All three students made substantial improvements in their understandings, with Pat and Tina showing the second highest improvement in their groups and Helen the highest.

Assertion 9/90

Students who do not appear to be overtly participating effectively in the group activities may still substantially improve their understanding of the concepts under investigation.

Many students retained alternative frameworks in the posttest and there were some instances of students changing from a scientific view to an alternative framework. For Proposition 1 in all the classes there was a substantial improvement in the

understanding that a battery did not have an electric current when it was isolated. However, in both Mr Avery and Ms Brown's classes many students continued to hold the view that once wires were connected, even if they were not connected in a circuit, there was an electric current. This alternative framework has been frequently reported in studies (Dupin & Joshua, 1987; Osborne & Gilbert, 1979). Neither Mr Avery nor Ms Brown gave this aspect of the proposition much attention although it was discussed in Mr Avery's class. However, Mr Carter performed a quite dramatic demonstration, involving many of the students in the class, which showed this fact clearly. This supports Assertion 9/86 (Students are more likely to learn where teachers are knowledgeable and use many strategies) but also introduces a new assertion.

Assertion 9/91

Dramatic or interesting methods of illustrating phenomena result in more learning taking place.

Students are often unaware of where joins need to be in a circuit (Arnold & Millar, 1987; Fredette & Lockhead, 1980; Tasker & Osborne, 1985). Many students in Ms Brown and Mr Carter's classes considered that joins to either side of the globe would result in a working circuit if the battery connections were correct, with fewer students in Mr Avery's class making this error. This is linked to Assertions 5/14 (Information provided in the curriculum may not be effectively used) and 5/15 (Teachers may not recognise the effects of omitting a part of the curriculum). The students did not draw all their non-working circuits which would have given them more opportunity to recognise the importance of the position of the wires on the globe, but also neither Ms Brown nor Mr Carter used the diagram provided with the lesson outlines that showed the full circuit, including the connection through the globe, which was often used by Mr Avery. This also supports Assertion 9/87 (Omitting parts of the curriculum results in students not changing non-scientific understandings) and relates to Smith and Neale's (1989) discussion of the effects of misuse of curriculum materials.

Students unscientific conceptions related to the amount of current in parts of a circuit and of the direction of current flow have frequently been reported (eg. Heller & Finley, 1992; Tasker & Osborne, 1985; Shipstone, 1984). The concept that there is the same amount of electric current in all parts of a circuit was poorly addressed by the teachers and poorly understood by the students. Again, this relates to the teachers' use of the curriculum materials and supports Assertion 9/87 (Omitting parts of the

curriculum results in students not changing their non-scientific understandings) and also Assertion 5/14 (Information provided in the curriculum may not be effectively used) and 5/15 (Teachers may not recognise the effects of omitting a part of the curriculum), but it may also relate to the teachers' lack of knowledge (Assertion 5/25, 'Teachers who lack science knowledge may accept or reinforce incorrect understandings and Assertion 5/26, (The teacher's knowledge affects the quality of the explanations).

The fact that the students in Ms Brown and Mr Carter's classes had a limited understanding of the direction of current flow can also be related back to poor use of the curriculum materials. However, it also reflects Mr Carter's understanding as, although he checked the correct direction of current flow with another teacher and had the reasons explained, he originally intuitively felt that current flowed from positive to negative. In the first lesson he stated the correct direction of flow, but in all subsequent lessons he reverted to his initial understanding.

Assertion 9/92

Where teachers have non-scientific understandings these are hard to change and may be passed on to the students.

This Chapter is the final chapter which describes and analyses what happened in the lessons. The next chapter collates and categorises the assertions that have been generated in the last five chapters and produces overarching assertions.

CHAPTER 10

Synthesis of Assertions

Introduction

The nature of this study enabled the researcher to analyse not only whole-class and group interactions, but also their relationships and the links across the learning process. However, the breadth of the data and the number of factors that may have impinged on the learning makes a direct causal relationship between any individual teaching process and learning outcome impossible to verify. Nevertheless, it is possible to establish links between combinations of characteristics of the learning environment and changes that occurred in understandings. The discussion in this Chapter synthesises more general assertions from those previously developed about these relationships. However, further studies would be necessary to test any potential generalisability of the findings.

It was proposed in the literature review that conceptual growth and change was facilitated by interactions between teachers and students through whole-class and group activities and discussion, which provided opportunities for learning. Combinations of teacher and student behaviours provided opportunities for learning in all classes to a greater or lesser degree.

Summary and Analysis of Assertions

The assertions generated in Chapters 5 - 9 (Appendix 8) have been grouped to produce general assertions, which summarise specific teaching and/or learning behaviours. These have then been collated to produce overarching assertions which summarise the findings of this study (Figure 10.1). Where assertions have been used in more than one situation, they have been indicated with an asterisk.

Assertion	Focus of General Assertion		Focus of Overarching Assertion
5/2, 5/3 6/58*	A	Classroom ethos	1. The effect of classroom ethos and teacher manner on student engagement
	B	Supportive teachers	
5/14, 5/15, 9/87 6/46	C	Inappropriate use of curriculum materials	2. Changes in curriculum materials and the effect on students' learning outcomes
	D	Appropriate changes to curriculum materials	
5/1, 6/45 5/6, 5/7, 5/22, 5/5 5/4, 6/47, 6/48*, 7/80 6/48*, 8/85	E	Quantity of management interactions	3. Organisation of behaviour and task management
	F	Behaviour management strategies	
	G	Task instructions	
	H	Time management	
5/25, 5/17, 9/92, 6/52*, 8/83 5/20, 5/21, 5/26, 5/27, 9/86*	I	Teacher knowledge and alternative frameworks	4. The quality of teachers' understanding and its effect on student learning outcomes
	J	Teacher knowledge and explanation quality	
5/11, 5/12, 5/28, 5/29, 5/30, 5/9, 5/10 5/8, 5/35, 5/23, 5/24, 5/41, 5/13, 5/16, 5/40, 5/36, 9/86*, 9/91 5/31, 5/32, 5/33, 5/34, 9/88 6/50, 6/51, 6/52*, 6/53, 6/54, 6/58*, 6/44, 6/49*	K	Teachers' questioning strategies	5. The effect of teachers' discussion styles on students' engagement; the teachers' knowledge of students' understandings; and the students' learning outcomes
	L	Teacher discussion and demonstration style	
	M	Reviews of completed work	
	N	Interactions during teacher visits to groups	
5/18, 5/19, 5/42* 5/37, 5/38, 5/39	O	Use of scientific terminology	6. The effect of teacher language use on student responses
	P	Quality of student answers	
7/60, 7/69, 7/70, 7/72* 7/61, 7/62	Q	Choice of group members	7. The effect of cooperative groups and effective leaders on work completion
	R	Leadership in groups	
6/56, 7/65, 7/68, 7/64, 7/63, 9/89 7/59, 7/71, 7/73, 7/74, 7/75, 7/76, 7/77, 7/81	S	Group work skills	8. The effect of appropriate group work skills on efficient functioning of groups
	T	Group discussion skills	
5/42*, 7/78 6/43, 7/67, 7/79, 6/49*	U	Student statements in group discussions	9. The effect of teacher visits to groups on group behaviours and discussion
	V	Changes in group members' behaviours during teacher visits	
6/57 7/72*, 6/55	W	Teacher and student management of group work	10. The effect of teacher and student management of difficulties in group work on students' group work skills
	X	Teacher and student management of group practical work	
7/66, 9/90 8/84, 7/82	Y	Learning by passive students	11. Learning that occurs when the process is not obvious
	Z	Learning in different situations	

Figure 10.1. Relationships between assertions, general assertions and overarching assertions, and focus of general and overarching assertions

Although there are only two general assertions supporting the first overarching assertion, classroom ethos was seen to be an important aspect of the study as it related to the students' willingness to participate, and consequently affected most occasions when learning would occur.

GENERAL ASSERTION A	
A friendly classroom with a supportive teacher encourages student engagement and participation.	
Assertion 5/2	When the classroom is friendly, students are more likely to participate fully in both the discussions and the activities, offering ideas and suggestions and questioning the teacher's statements.
Assertion 5/3	Students' enthusiasm may be increased by the teacher's willingness to listen to and comment on student successes and ideas either in whole-class or individual settings.

In classrooms where the students feel at ease and the teacher is friendly, the conversation is likely to be more open and the students more enthusiastic. The students are more willing to attempt to justify their answers and ask questions, resulting in the teachers having more opportunities to recognise students' alternative frameworks and facilitate the development of more scientific understandings. If the classroom ethos is less supportive, the students are only willing to give limited answers and are less likely to question anything that the teacher says or become involved in discussions.

GENERAL ASSERTION B	
When teachers who are supportive and willing to listen to the students visit groups, the students will offer their understandings and ideas for evaluation and comment by the teacher.	
Assertion 6/58*	Students may use teacher visits to their group to check their understandings and/or that they are working correctly on the assigned practical task.

The teacher's attitude and classroom ethos also affects the quality of the students' questions and responses during group work, with students who have supportive, friendly teachers offering understandings and ideas when the teacher visits the group. However, the students' input during teacher visits will often be limited to factual questions if the teacher is less supportive of student ideas. These first two General Assertions are summarised as Overarching Assertion I:

Overarching Assertion 1

When the classroom is supportive and friendly and the teachers demonstrate an interest in the students' ideas and discoveries, the students are more likely to become engaged in learning.

Many studies have shown that teachers often do not follow the curriculum materials and may make changes which limit some of the learning (eg. Smith & Neale, 1989). It is possible for teachers to effectively adapt the materials if they have sufficient knowledge of the topic and if they ensure that all the learning situations are included. The curriculum materials in the study were designed so that teachers could use them as they wished, but it was explained that the group activities needed to be completed, the focus questions needed to be discussed and the objectives needed to be reached. However, these instructions were not always followed.

GENERAL ASSERTION C

If curriculum materials are not used as intended by the curriculum writers the opportunities for learning may be reduced.

Assertion 5/14

Information provided in curriculum materials may not be effectively used.

Assertion 5/15

When parts of a lesson are missed, teachers do not always recognise that they are omitting a part of the curriculum and this will have a negative impact on learning.

Assertion 9/87

Where teachers omit parts of the curriculum or do not use the supplied materials, students may not be given the opportunity to develop scientifically acceptable understandings.

When curriculum materials are not used as intended, important segments may be omitted and consequently the learning opportunities for the students may be limited. This may result in students retaining their non-scientific understandings. If the teacher is unaware that s/he has changed the curriculum materials, s/he will be unlikely to remediate the situation.

GENERAL ASSERTION D

Where a teacher has sufficient knowledge of a topic, s/he may be able to make changes to the curriculum materials which do not adversely affect the learning opportunities.

Assertion 6/46

Curriculum materials may be manipulated to support a teacher's style of teaching but still maintain the integrity of the materials.

Teachers with a good knowledge of the topic and who are also aware of the idiosyncratic ideas that students might hold may be able to effectively change the teaching materials without diminishing the learning outcomes. These changes may be necessary to support a particular teaching style or the needs of a group of students. These two general assertions lead to Overarching Assertion 2:

Overarching Assertion 2

When teachers do not use the curriculum materials as intended, the students will be disadvantaged unless the teacher has a very good understanding of the topic and is able to provide an alternative sequence of learning experiences that provide opportunities for developing the intended learning outcomes.

Some classrooms are very teacher directed. When the teacher takes responsibility for all the occurrences during a lesson, s/he spends much of his/her time managing tasks and behaviours and this may limit the time available for general discussion and the development of explanations for the phenomena being investigated. Students in Year 7 should be able to manage the tasks after initial instructions and given minimal on-going direction from the teacher, particularly when they also have the instructions on worksheets. However, teachers are sometimes reluctant to pass responsibility to the students. Unfortunately, when students are not allowed independence and responsibility, this affects their group work and they are less likely to make decisions without the teacher's input, adding to the teacher's workload.

GENERAL ASSERTION E

A large proportion of the interactions that occur in classrooms are related to management of behaviour or tasks.

Assertion 5/1

Approximately half of the interactions in primary science lessons of the type studied relate to management either of the task or of student behaviour.

Assertion 6/45

In most classes during group work, the number of utterances from teachers or students that relate to management, either of the task or of student behaviour, is higher than those related to developing understandings.

During whole-class discussions, about half the time is used for management, either explaining and managing the task, or managing behaviour. Where the class is

more teacher directed, the level of management interactions is higher. During teacher visits to groups, the management interactions are generally very high, although, where the teacher focusses on developing understandings, they may be lower. This management focus is also seen in group work when the teacher is not in attendance, with most student interactions related to managing the task.

GENERAL ASSERTION F
Pro-active strategies can be used to improve student attention and engagement, and reduce the need for overt student behaviour management.
Assertion 5/6 When students are moved to face the teacher during whole-class discussions student attention and participation is improved.
Assertion 5/7 When materials are not available during the discussions, student attention and participation is improved.
Assertion 5/22 When students are moved to the front of the class during discussions or demonstrations, student attention and participation is improved.
Assertion 5/5 Less intrusive use of control strategies helps to ensure that lesson flow is maintained.

Where behaviour is managed pro-actively, by organising situations and tasks so that there is less opportunity for negative behaviours, management problems are fewer. However, in any classroom, situations may arise where the teacher needs to address poor behaviour by a student. When these incidents are addressed quietly by the teacher with minimal interruption to the lesson, the lesson flow can be maintained and students are more likely to be able to follow the construction of explanations during the discussion.

GENERAL ASSERTION G
Task instructions should allow freedom of progress by students to encourage them to be self reliant and to stay on-task and involved.
Assertion 5/4 A variety of methods can be used to provide instructions for activities, some of which are imposed and some which allow students to exercise independence.
Assertion 6/47 A quick initial check of all groups ensures students understand the task and have the correct materials.

Continued

<p style="text-align: center;">GENERAL ASSERTION G <i>continued</i></p> <p style="text-align: center;">Task instructions should allow freedom of progress by students to encourage them to be self reliant and to stay on-task and involved.</p>
<p>Assertion 6/48*</p> <p>Student involvement in activities is increased when they are able to progress at their own rate and they become bored and off-task when they are required to wait for instructions from the teacher.</p> <p>Assertion 7/80</p> <p>Students who are used to working independently of the teacher maintain this when working in groups</p>

The varying methods of giving and reinforcing instructions for tasks emphasised the differing attitudes of the teachers towards their students and towards the learning process. Independent students demonstrated an ability to make decisions by reference to the worksheets or by asking the teacher. In teacher directed classrooms, the teacher's role was seen to be one of managing the task and groups expected reinforcement of instructions and teacher attendance to ensure the activity was understood, and instructions as to when the next activity could be started. This resulted in a teacher work-load that limited the time available for conceptual discussion with the groups. Because the curriculum materials allowed some freedom in teaching style, one teacher reworded the instructions into open-ended tasks which were couched in a way that gave the students more freedom in their approach to the problems.

<p style="text-align: center;">GENERAL ASSERTION H</p> <p style="text-align: center;">The time allowed for task completion and discussion needs to be such that students have enough time to complete the work but not too much so that they become off-task.</p>
<p>Assertion 6/48*</p> <p>Student involvement in activities is increased when they are able to progress at their own rate and they become bored and off-task when they are required to wait for instructions from the teacher.</p> <p>Assertion 8/85</p> <p>Sufficient time needs to be allowed in all lessons for the students to engage in discussion and reflection.</p>

Although the time allowed for discussion must be sufficient to allow students to cover the discussion topics, management problems may occur when the students are given too much time to complete tasks, particularly discussions. This results in students becoming off-task and often discussing topics unrelated to science. When this occurs it is likely that the science based discussion will be difficult to recall, and the students may find it difficult to contribute ideas to any subsequent whole-class discussion. If an activity is involved, the students may dismantle any circuits that they have constructed

and use the circuit components for other purposes. This, again, may break the lesson sequence as the constructed circuit might not only be the topic of a discussion, but may also be the basis of the next activity, and if it is not available, the students may not be able to ascertain how to continue the activity.

This wide range of general assertions (E - H) leads to Overarching Assertion 3:

Overarching Assertion 3

If behaviour management and task management are organised so that overt control mechanisms are used less, the lesson will flow smoothly and students are more likely to stay on task with less teacher interruptions, and the time available for conceptual discussion will be increased.

Teacher knowledge of the topic and of alternative frameworks has an impact on the way the lessons are conducted and the ideas that are available for consideration.

GENERAL ASSERTION 1
Teachers who have a restricted understanding of the topic and/or have alternative frameworks themselves are limited in their ability to recognise student explanations based on alternative frameworks.
Assertion 5/25 Where a teacher's understanding of a concept is limited s he may not recognise students' explanations based on alternative frameworks and may accept or reinforce these.
Assertion 5/17 Some teachers demonstrate little knowledge of students' alternative frameworks.
Assertion 9/92 Where teachers have non-scientific understandings these are hard to change and may be passed on to the students.
Assertion 6/52* Acceptance in the group discussion of students' answers that are based on unscientific beliefs may result in students retaining incorrect understandings if the concept is not later discussed and clarified in the whole-class discussion.
Assertion 8/83 Teachers who are less aware of alternative frameworks may, by restricting discussion either in group work or in whole-class discussions, not give students the opportunity to recognise and discuss other ideas.

Where teachers are unaware of alternative frameworks they tend to accept the first correct answer and move on. This results in the students not being given the

opportunity to recognise other understandings or present their own ideas and discuss and test these. The information is presented as being correct and there is little discussion, particularly in the less supportive classrooms. In more supportive classrooms, there may be some questioning by students, which may generate discussion. However, the teacher may state that the student's ideas are incorrect and repeat the correct answer, restricting discussion and learning opportunities for the student. If the teacher has non-scientific beliefs these will affect their responses to questions and the students may also develop non-scientific understandings.

GENERAL ASSERTION 1
The teachers' knowledge of the topic affects their ability to present clear, unambiguous and scientifically acceptable explanations using a variety of supporting strategies.
<p>Assertion 5/20 Teachers with a good knowledge of the topic are able to use a wider variety of contexts for developing ideas.</p> <p>Assertion 5/21 Teachers with a good knowledge of the topic allow the ideas and activities to be extended by students and are able to comment on and evaluate these.</p> <p>Assertion 5/26 The teacher's knowledge of the topic affects the quality of his/her explanations.</p> <p>Assertion 5/27 Clear and accurate explanations from the teacher give the students the opportunity to develop scientifically acceptable understandings.</p> <p>Assertion 9/86* Where teachers are knowledgeable and use a wide variety of methods to illustrate and explain phenomena with students engaged in discussion and constructing ideas, the students have more opportunities for learning and are more likely to reach scientifically acceptable understandings.</p>

The teacher's lack of knowledge about the topic can also restrict discussion as the teacher may accept the first answer that s/he considers correct, and may not allow any further discussion. Teachers with limited knowledge of the topic tend to only use a limited range of strategies and contexts for developing concepts and often conduct discussions that are less interesting and which may include unclear explanations. Their methods of presenting the topic are likely to be more restricted and the curriculum materials may be misunderstood and/or misused. Because of the limited range of explanations that are available to students, the understandings that they develop are less likely to be complete.

These general assertions (I and J) lead to Overarching Assertion 4:

Overarching Assertion 4

When a teacher’s understanding of the topic and his/her knowledge of alternative frameworks is restricted, this will affect the quality of explanations and discussion and limit the learning opportunities that are available to the students.

For learning to occur, students need to be engaged in the whole-class and group discussions, and the use of a variety of strategies will improve their attention. It has already been suggested that teacher knowledge may have an effect on the range of strategies used and that teachers may not use the curriculum materials effectively, possibly resulting in some of the suggested strategies (eg. demonstrations) not being used. The teacher’s range of questioning techniques may also have an effect.

GENERAL ASSERTION K

Questioning techniques that include open and closed questions, questioning a variety of students and gaining a variety of responses, allow the teacher and students to recognise the range of ideas and encourage students to stay involved and engaged in constructing and testing explanations.

Assertion 5/11

A variety of types of questions elicits a wider range of responses from the students.

Assertion 5/12

Open questions may be used in many situations to generate ideas and discussion.

Assertion 5/28

The tone of a teacher’s voice may cue the students to the correct response.

Assertion 5/29

The correct answer needs to be identified when a variety of responses are accepted for an open question.

Assertion 5/30

The generation of a variety of ideas leads students to recognise and question other’s ideas.

Assertion 5/9

Obtaining responses from many different students helps to maintain student interest.

Assertion 5/10

Questioning a variety of students allows the teacher to become aware of the range of understandings held by the class.

All of the teachers in this study used open questions but the way in which they were used affected the opportunities for learning. Where open questions are mainly used to elicit predictions about what might happen in an investigation, and any discussion

following the activity is negligible or limited by closed questioning, the students are not given an opportunity to relate their predictions to the results of the investigation and develop an understanding of why any difference occurred. Open questions may be effectively used in discussions following practical investigations to elicit a range of explanations for the observations made, evaluate these different views and then reach consensus round a scientifically acceptable explanation. Teachers who only question a limited range of students or who accept the first correct answer and do not engage in discussion following investigations, do not encourage student involvement or the development of understandings.

<p style="text-align: center;">GENERAL ASSERTION I</p> <p style="text-align: center;">Teachers who use animated discussions and a variety of strategies to help develop understandings and who encourage student participation, allow more opportunities for learning and maintain the students' attention.</p>
<p>Assertion 5/8 Animated whole-class discussion using a variety of strategies helps to maintain student interest and engagement.</p> <p>Assertion 5/35 The students' involvement in the construction of explanations during discussions helps to maintain interest and allows them more opportunities to develop understandings.</p> <p>Assertion 5/23 Where student blackboard drawing is completed when the other students are still working, the students are more likely to pay attention when the drawings are brought to their notice.</p> <p>Assertion 5/24 Where blackboard drawing is accompanied by teacher explanations, the students' attention is better and they have more opportunity to recognise the ideas of other class members.</p> <p>Assertion 5/41 When students are involved in evaluating and correcting blackboard diagrams, there are more opportunities for the development of scientifically acceptable understandings.</p> <p>Assertion 5/13 The use of a variety of teaching aids and diagrams on the blackboard or from posters, with clear explanations may assist in the development of scientifically acceptable understandings.</p> <p>Assertion 5/16 Using analogies helps students to relate abstract ideas to things that they understand and provides opportunities for learning.</p> <p>Assertion 5/40 When students are involved in meaningful demonstrations they and the rest of the class are more attentive.</p>

Continued

<p align="center">GENERAL ASSERTION L <i>continued</i></p> <p align="center">Teachers who use animated discussions and a variety of strategies to help develop understandings and who encourage student participation, allow more opportunities for learning and maintain the students' attention.</p>
<p>Assertion 5/36</p> <p>When students are interested and involved in the discussion and activities they are more likely to ask questions and offer suggestions.</p> <p>Assertion 9/66*</p> <p>Where teachers are knowledgeable and use a wide variety of methods to illustrate and explain phenomena with students engaged in discussion and constructing ideas, the students have more opportunities for learning and are more likely to reach scientifically acceptable understandings.</p> <p>Assertion 9/91</p> <p>Dramatic or interesting methods of illustrating phenomena result in more learning taking place.</p>

General Assertions K and L have links back to the Overarching Assertion 3 addressing task management. Students become bored and restless when they are not physically or verbally engaged in the discussions and/or demonstrations and, where teachers have students drawing on the blackboard with little explanation or discussion whilst others watch, they lose the attention of the class. Knowledgeable teachers are able to use a wide variety of strategies to demonstrate concepts and this variety not only helps maintain interest, it also gives students more opportunities to develop understandings. Students are generally keen to participate in demonstrations and engaging their assistance helps maintain their interest.

<p align="center">GENERAL ASSERTION M</p> <p align="center">Teachers who offer regular reviews of work that has been done, and link it to the current activities give students more opportunity' to develop a better understanding of the topic.</p>
<p>Assertion 5/31</p> <p>Regular reviews give students who have been absent for one or more lessons an opportunity to find out what has been covered.</p> <p>Assertion 5/32</p> <p>Students have more opportunities to construct understandings when time is allowed for regular, effective reviews of work to be conducted.</p> <p>Assertion 5/33</p> <p>Reviews directed by the teacher are likely to be more comprehensive than those where student responses guide the discussion.</p>

Continued

GENERAL ASSERTION M *continued*

Teachers who offer regular reviews of work that has been done, and link it to the current activities give students more opportunity to develop a better understanding of the topic.

Assertion 5/34

Where links are not clearly made between parts of a lesson and/or individual lessons, students may have more difficulty constructing understandings.

Assertion 9/88

Where effective reviews are not conducted it is likely that any improvement in understanding will be limited.

The use of reviews is important in science as students often cannot make the conceptual jump that enables them to link parts of a lesson together, and often have difficulty remembering what happened the previous week. It appears that some teachers tend to treat the individual lessons more or less in isolation with few links made to previous work. This is a particular problem in primary science where there may be only one lesson a week. Generally, a series of lessons is intended to build on previous understandings, either within the lesson or between lessons, and if these are not reviewed frequently the links will not be made, and the necessary understandings may not develop.

GENERAL ASSERTION N

Teacher's visits to groups may be used to develop conceptual understandings but teachers need a way of ascertaining the students' understandings, and need to ensure that students' unscientific explanations discussed in the group are evaluated in a whole-class discussion with consensus reached round a scientifically acceptable explanation.

Assertion 6/50

Listening to group discussion or reading student notes enables the teacher to ascertain student understandings and pose questions to facilitate the development of ideas and understandings of students in that group.

Assertion 6/51

Teacher visits to groups may be used to facilitate the development of conceptual understandings through discussion and questioning.

Assertion 6/52*

Acceptance in the group discussion of students' answers that are based on unscientific beliefs may result in students retaining incorrect understandings if the concept is not later discussed and clarified in the whole-class discussion.

Continued

GENERAL ASSERTION N *continued*

Teacher's visits to groups may be used to develop conceptual understandings but teachers need a way of ascertaining the students' understandings, and need to ensure that students' unscientific explanations discussed in the group are evaluated in a whole-class discussion with consensus reached round a scientifically acceptable explanation.

Assertion 6/53

Information and ideas developed with or given to individual groups also need to be given to the whole class.

Assertion 6/54

Visits to groups may be used to review previous work or understandings and make links to current understandings.

Assertion 6/58*

Students may use teacher visits to their group to check their understandings and/or that they are working correctly on the assigned practical task.

Assertion 6/44

Where student interactions are higher than that of the teacher, the teacher has more opportunity to recognise students' understandings.

Assertion 6/49*

Because of the demands of supervising group work in a given class, teachers may miss visiting some groups which may disadvantage those groups.

Discussions related to the development of understanding do not only occur in whole-class situations, but may also occur in small group discussions. especially when teachers visit groups. Teachers use a variety of strategies to ascertain what the students are thinking and, in classes where students offer limited information to the teacher. the teachers may read and comment on the students' work. This strategy is used to a lesser extent in classrooms where students offer more information. It is an effective way of checking understandings after a whole-class discussion has generated ideas and the students are recording information. The teacher/student discussion in groups may generate several different understandings, particularly if the group is willing to listen to other members' ideas, but the teachers may not always indicate the correct response during the discussion. In this situation, the ideas need to be discussed with the whole-class, giving those groups that have not been visited the opportunity to recognise other understandings. Teachers, when they are less knowledgeable, may also accept inappropriate explanations from groups. If the concept is discussed later in a whole-class setting, a more scientifically acceptable answer may be generated and recognised.

The quality of discussions is an important factor determining opportunity for learning in science classrooms and General Assertions K–N lead to Overarching Assertion 5:

Overarching Assertion 5

The strategies that teachers use in discussions have an effect on the engagement or otherwise of the students; the knowledge the teacher gains of student understanding; the explanations that are constructed; and the opportunities for student learning.

Introducing students to scientific language and discourse is an important aspect of science lessons, and much research has occurred around this theme.

GENERAL ASSERTION O
Neither teachers nor students use science terms effectively.
Assertion 5/18 Teachers may not use scientific terms consistently.
Assertion 5/19 Teachers may not explain all of the scientific terms they use.
Assertion 5/42* Students are unlikely to use many new scientific terms in their discussions.

The teachers in this study did not use scientific terms consistently or explain them clearly. Even teachers who have a good understanding of the topic may not be consistent in their use of terminology, and they may assume that students understand the terms used. Primary science lessons are complex environments, with a variety of tasks to be completed and a wide range of interactions with students. These factors and a limited knowledge of the concepts may contribute to poor use of science terms. Teacher use and explanation of terms does encourage students to use them but not to the extent expected and more opportunities and encouragement may be needed.

GENERAL ASSERTION P

Student answers may be full and detailed or fragmented and teachers need to respond by summarising as necessary.

Assertion 5/37

The students' ability to extend or justify their answers allows more complete answers to be generated and gives teachers more opportunity to recognise understandings.

Assertion 5/38

Where explanations or student answers are fragmented it is more difficult for other students to construct understandings.

Assertion 5/39

Where teachers need to use many questions to help students respond, the fragmented answers need to be summarised to clarify the explanation.

The classroom ethos and possibly the teacher expectations affects the way students respond to questions. There was an expectation in some situations that the students explain fully and justify their answers; but in others the answers were very limited and often needed many questions by the teacher to generate a complete answer. If the answer is not then summarised it is difficult for students to recognise the complete explanation. When full answers are given by the students, their understandings are more easily recognised, and are more easily understood by the students.

The language and explanations used in science classrooms are often less explicit than would be hoped for and these general assertions (O and P) lead to Overarching Assertion 6:

Overarching Assertion 6

Where teachers provide good explanations; science terms are clearly explained and used consistently; and student answers are summarised where necessary; students may develop better understanding, and their explanations will include more scientific terms than where these conditions do not apply.

In primary classrooms, the teacher may select group members to meet specific criteria as was the case in this study. However, when selecting group members, the teacher does need to consider the possible group dynamics and ensure the group is likely to be functional.

GENERAL ASSERTION Q
Group members need to be chosen carefully as the social dynamics of a group may adversely affect the learning that occurs and the number of tasks that are completed.
Assertion 7/60 The choice of students to work together in groups needs to be planned carefully to avoid dysfunctional groups.
Assertion 7/69 The social dynamics of the group may affect their on-task behaviours.
Assertion 7/70 Groups which infrequently engage in extended social conversation demonstrate more success in completing tasks.
Assertion 7/72* Students who do not complete practical activities may find it more difficult to develop understandings

In any group, situations may arise where students do not relate well, but, if the group is generally cohesive, these may not cause difficulties. However, if a group is dysfunctional and the students do not have good group skills, it is unlikely to perform well and the set tasks may not be completed. It is possible for a group to relate so poorly that little learning can occur with the students demonstrating little interest in the activities and concerned only with the social relationships in the group. Most teachers would be aware of the group dynamics of the students and would avoid grouping certain students together but, when it does happen, the learning will be limited.

GENERAL ASSERTION R
Groups need to be structured so that at least one student is capable of taking the leadership role.
Assertion 7/61 A student may direct the group in an unobtrusive manner but still have the role of leader.
Assertion 7/62 The presence of a leader in a group, even if this role is rotated between students, facilitates group work.

Leadership roles in groups can be taught and it is apparent that good leaders assist the groups in their task management and completion. The leadership role can be dynamic, changing from student to student as the necessity arises, or may be one student who helps direct the flow of the work over the whole lesson. Leaders do not need to be overt and possibly challenging, but a quiet leader can be just as helpful to the progress of work.

These General Assertions (Q and R) lead to Overarching Assertion 7:

Overarching Assertion 7

Where groups are cooperative and have an effective leader, they are likely to complete more tasks than groups that are uncooperative and lack effective leadership.

Group activities are frequently used in primary classrooms, particularly in science lessons, but the students may lack the necessary skills for effective group work.

GENERAL ASSERTIONS

Students often lack the skills that allow a group to be cooperative and smooth running resulting in inattentiveness by students who are less involved.

Assertion 6/56

Students need to be taught how to work collaboratively and to solve problems within a group situation.

Assertion 7/65

Students in groups need to ensure that all members are involved in the task.

Assertion 7/68

Groups need to be taught strategies to enhance attentiveness.

Assertion 7/64

Students with less knowledge in a mixed ability group may not participate as effectively in activities and discussions as those with more knowledge.

Assertion 7/63

Individual group members, either male or female, may use the equipment to the exclusion or partial exclusion of others.

Assertion 9/89

Groups that do not have the skills to work cooperatively are less likely to improve their understanding of the concepts under investigation.

Group work skills include ensuring that all members are working together and that everyone has an opportunity to participate, but also that everyone is attentive and aware of what is happening. When all group members do not participate in the activities, the non-participants may lose interest in the group based tasks although they may still improve their understandings. The lack of participation may be because other group members dominate the use of the equipment or the discussion, but may also be because of an inability to stay on-task during group work.

GENERAL ASSERTION T
Students often find it difficult to discuss productively, share ideas and respond helpfully during group work.
<p>Assertion 7/59</p> <p>Students with a greater knowledge of the topic than other group members may offer their information or ideas in a helpful or dictatorial manner which may affect the development of understanding.</p> <p>Assertion 7/71</p> <p>Groups which engage in positive interactions demonstrate more success in completing tasks.</p> <p>Assertion 7/73</p> <p>Friendly interactions and effective discussion skills provide more opportunities for learning and therefore better construction of understandings.</p> <p>Assertion 7/74</p> <p>Students who engage in cooperative discussion give all students in the group opportunities to develop understandings.</p> <p>Assertion 7/75</p> <p>Answers which include explanations allow more opportunity for discussion and learning.</p> <p>Assertion 7/76</p> <p>Students who are able to accept and build on comments from others have more opportunities to develop understandings.</p> <p>Assertion 7/77</p> <p>Students who engage in incidental discussion during activities as well as the discussions suggested by the teacher, have more opportunities to develop understandings.</p> <p>Assertion 7/81</p> <p>A framework for discussion, eg. a list of questions that needs responses, encourages all the students to respond in a discussion. However, it may not necessarily result in good discussion.</p>

The skills of small-group discussion may be influenced by good whole-class discussion, however, students need to realise that small-group discussion is different and requires different skills. Group dynamics have a big impact on the discussion that occurs. More knowledgeable students sometimes over-rule suggestions made by less knowledgeable students, with the effect of alienating them from the discussion and reinforcing their often more limited participation. It is unlikely that negative comments would be made during whole-class discussions but they do occur in group discussions and positive, friendly interactions are important to promote good discussion and maintain cohesion in the group. Students also need to realise that, to develop understandings and to assist other group members, discussion needs to occur outside that prescribed by the teacher. It did occur in the class where students were more independent and where the class discussion was of a higher quality than the other two

classes which may indicate that good whole-class discussion may improve small group discussion. The use of frameworks for discussion in the form of the supplied focus questions, helped to direct the students' attention towards the topics for discussion, but, where the students did not have good discussion skills, the quality of the discussion was not improved.

The discussion of these General Assertions (S and T) leads to Overarching Assertion 8:

Overarching Assertion 8

Before a group can function efficiently, the members need to develop the appropriate group work skills including those of cooperation, on-taskness and discussion.

The difficulties that students have in group work can be alleviated by teacher visits to the groups.

<p>GENERAL ASSERTION U</p> <p>Group discussion during group work time is likely to be restricted to short statements with limited use of scientific terms.</p>
<p>Assertion 5/42*</p> <p>Students are unlikely to use many new scientific terms in their discussions.</p> <p>Assertion 7/78</p> <p>Group discussion in primary schools is often only made up of short statements.</p>

Group discussion is very different to that which occurs in the whole-class situation. Responses in whole-class discussions are generally longer and may include explanations, whereas those in groups usually consist of short statements. Student interactions are frequently related to managing the task and often the only scientific terms used are those which are object names, such as battery and globe. Students often only engage in conceptual discussion when requested by the teacher and they need to learn to recognise opportunities when conceptual discussion would be appropriate.

<p style="text-align: center;">GENERAL ASSERTION V</p> <p style="text-align: center;">When groups are visited by teachers, the group members' attentiveness improves as does the quality of the discussion.</p>
<p>Assertion 6/43</p> <p>During teacher visits to groups, the number of interactions from the teacher and the students are usually similar in quantity although teacher utterances are generally longer.</p> <p>Assertion 7/67</p> <p>The attendance of a teacher at a group improves group attentiveness.</p> <p>Assertion 7/79</p> <p>Teacher support enables more constructive discussions to occur.</p> <p>Assertion 6/49*</p> <p>Because of the demands of supervising group work in a given class, teachers may miss visiting some groups which may disadvantage those groups.</p>

When teachers do attend a group, even if they do not get involved in the discussion, their presence generally encourages the students to pay more attention to the task and may encourage them to ask questions or ask for help if the teacher is approachable. When teachers become involved in the discussion, they may be able to scaffold the discussion so that the students have an opportunity to listen to other ideas and build on others' understandings. However, it is possible that time constraints will result in some groups not being visited and these students are likely to be disadvantaged. General Assertions U and V lead to Overarching Assertion 9:

<p style="text-align: center;">Overarching Assertion 9</p> <p style="text-align: center;">Where the group members do not have the skills for group work, the teacher's attendance at the group improves the attentiveness of students and the quality of the discussion.</p>
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The teacher's management style also influences their actions when students are having difficulty with practical work.

<p style="text-align: center;">GENERAL ASSERTION W</p> <p style="text-align: center;">When teachers assist in the management of group work it may improve lesson flow but, if students are not involved in the solution of problems, the management strategies may not be effective.</p>
<p>Assertion 6/57</p> <p>Turn-taking and cooperation in groups may be maintained by low key management or strong management solutions. However, imposed management solutions may only work for a limited time.</p>

Students need to learn the skills that will make their group work productive (Overarching Assertion 8) and, if these are taught, the group work should improve and fewer problems should occur. However, where skills are limited and students do not take responsibility for the task, teachers may need to intervene. Strategies where the students are involved in solving the problems are more effective than teacher imposed solutions, as these are not maintained by the students without on-going teacher intervention.

<p style="text-align: center;">GENERAL ASSERTION X</p> <p style="text-align: center;">Where students are unable to complete tasks, teachers may correct problems for them or assist them to solve problems.</p>
<p>Assertion 7/72*</p> <p>Students who do not complete practical activities may find it more difficult to develop understandings.</p> <p>Assertion 6/55</p> <p>Teachers find different ways of helping students with practical tasks, some of which may allow the students more opportunity to learn than others.</p>

Students may be disadvantaged when they are unable to complete the practical tasks. Where teachers question the students to enable them to recognise where the error in the practical work may have occurred they provide better opportunities for learning, as the students need to become engaged in the problem and its solution. The students can then solve the problem themselves and correct it. However, when the teacher corrects the problem for the students, they have less engagement with the task and the opportunities for the student to learn are more limited.

General Assertions W and X lead to Overarching Assertion 10:

Overarching Assertion 10

When students are having difficulties either with tasks or with group skills, teachers should use ways of helping them that will improve their skills and understandings both of the task and group management.

When students are attentive and engaged in the lesson, it would be expected that learning would occur. However, it would appear that students may learn in situations that appear to be less conducive to learning.

GENERAL ASSERTION Y

Where students are not demonstrating overt attention during group activities and discussions, they may experience fewer learning opportunities but may still be assimilating information.

Assertion 7/66

The students' level of attention during group work may affect their opportunities to learn.

Assertion 9/90

Students who do not appear to be overtly participating effectively in the group activities may still substantially improve their understanding of the concepts under investigation.

It would be expected that students who did not appear to be overtly paying attention during the group work time would be disadvantaged. However, the results of this study indicated that, even when not appearing to be involved with the group tasks, some students still managed to improve their understandings substantially.

GENERAL ASSERTION Z

Student learning occurs in many situations.

Assertion 8/84

Even when information is not presented clearly and effectively by the teacher in the whole-class discussion students may still improve their understanding of a concept. This may be through whole-class interactions or from interactions with other group members.

Assertion 7/82

Even when students appear inattentive during whole-class discussions they may still be paying attention.

Student learning may occur in a variety of situations, the most overt of which is during whole-class discussions. However, when students do not appear to be attending during the whole-class discussions, they may be still listening to some of the explanations. They may also learn from other situations, including within group interactions, or from other class members. These two general assertions (Y and Z) lead to Overarching Assertion 11:

Overarching Assertion 11

Student learning may occur even when the process is not obvious.

Summary

This study has examined in detail, the teaching and learning behaviours in three primary science classrooms. The original intention of the study, to look at interactions, needed to be extended as there were many factors, such as the use of curriculum resources and management strategies, that influenced the interactions that occurred, and they could not be examined in isolation.

As described in Chapter 2, a wide variety of factors impact on the learning that occurs in primary science lessons. This study adds supporting data to many previous studies, but also offers new data and considers a wide range of factors that influence students' opportunities for learning in primary science lessons.

Classroom Ethos

With the very different classes that were investigated it was apparent how much the classroom ethos affected the lessons, particularly in whole-class discussions, and in the teachers' interactions with groups. Because of the willingness of the students to be more involved in lessons where the classroom was supportive and the teachers were friendly, the students had far more opportunities to question and to learn and the teachers had more opportunities to discover what the students were thinking. Motivation and the effect of the social environment has been discussed (Driver & Oldham, 1986) and Fraser (1991) related a positive classroom environment to improved student outcomes, but the affect on the involvement of students in science lessons in primary classes does not appear to have been considered. This factor appears to have had a major impact on learning as the students in the class that was very teacher-controlled with a

teacher that was distanced from the students, demonstrated considerably less involvement and showed less improvement in understanding.

Curriculum Use

The changes that teachers make to curriculum materials have been studied (Arditoglou & Crawley, 1990; Gilbert et al., 1982; Smith & Neale, 1989) and this study also recorded some inadvertent curriculum changes. However, in this study, some changes were made to fit the teaching style of the teacher and the learning style of the students. This does not seem to have been considered previously and, particularly in primary classrooms, is likely to occur, as teachers frequently adapt their teaching to suit the cohort with which they are engaged. Where changes made by teachers in this study were inappropriate, or sections of the curriculum were omitted it appears to have reduced opportunities for learning and students' development of scientific conceptions.

Types of Interactions

When the types of interactions were examined it was found that most were managerial, whether the discussions were with the whole class or in individual groups. Even in the classes where the students were allowed independence and demonstrated responsibility, there were more managerial utterances than any other type. It would be expected that the level of management in primary classes would be high, but at Year 7, students should need less teacher attention than in earlier grades. The level of managerial interactions is a concern because this must limit the time available for conceptual discussion. This was noticeable when the teachers were attending groups, as there was little conceptual discussion occurring in two of the three classrooms. Group interactions have been studied (Solomon, 1991; Webb, N., 1982, 1985) but there has been little discussion of the types of interactions that teachers engage in when visiting groups. In this study most interactions that teachers had with groups were not only managerial, but also tended to solve problems, either of behaviour or task, for the students. This limited the students' opportunities to develop group skills and develop more scientific understandings. When the teachers engaged in conceptual discussion with the groups the discussions were often inconclusive with students left with unscientific understandings, or unsure which answer was acceptable.

Discussions and Demonstrations

Teacher knowledge

The effects of teachers' knowledge on their science teaching have been extensively studied. This study has generated data that support the findings of

Arditoglou and Crawley (1990) and Smith and Neale (1981) that teachers often have scientifically incorrect understandings and also offers data from primary classes that support Hashweh's (1987) study that indicated that less knowledgeable secondary teachers were unable to recognise incorrect understandings held by students. There is also data from the study of primary science lessons to support the findings that Carlsen (1992) and Sanders et al. (1993) made in secondary science lessons. These indicated that teachers with less knowledge may limit the discussion; maintain tight control over the content and direction of the discussions; and allow students less opportunity to question and discuss thus reducing opportunities for learning.

Discussions

Much of the data generated about the level and type of questioning supported previous studies (eg. Cunningham, 1987; Gage & Berliner, 1992). However, this study has indicated that some teachers may only use open questions when predictions are required, rather than when explanations about phenomena are being generated. The information that was generated through discussions with groups was often not disseminated to the whole class, and, where the discussions with the groups did not reach closure, the concepts were often not clarified in the whole-class discussion.

It was also demonstrated that, to maintain the level of interest during class discussions and demonstrations, there needed to be variety and animation, and as many of the students as possible should be involved. Where the same types of demonstration were constantly used, or the discussion was not animated and interesting, the students became off-task. Any demonstrations needed to be visible to the students and it was better if the students were not distracted by equipment during demonstrations and whole-class discussions.

Berliner and Rosenshine (1977) and Tasker (1981) indicated the need for links to be made between and within lessons. This study confirms that primary teachers vary in their abilities to make links in science lessons and may not be aware that students may not connect parts of lessons or individual lessons together.

Many studies have looked at the use and understanding of scientific terminology in classrooms and, in this study, the teachers' use and explanations of terms was limited. However, in the class where the teacher did use more scientific terms consistently and did explain many of them, the students generally only used the terms that were object labels, and did not use many of the conceptual terms.

Group Work

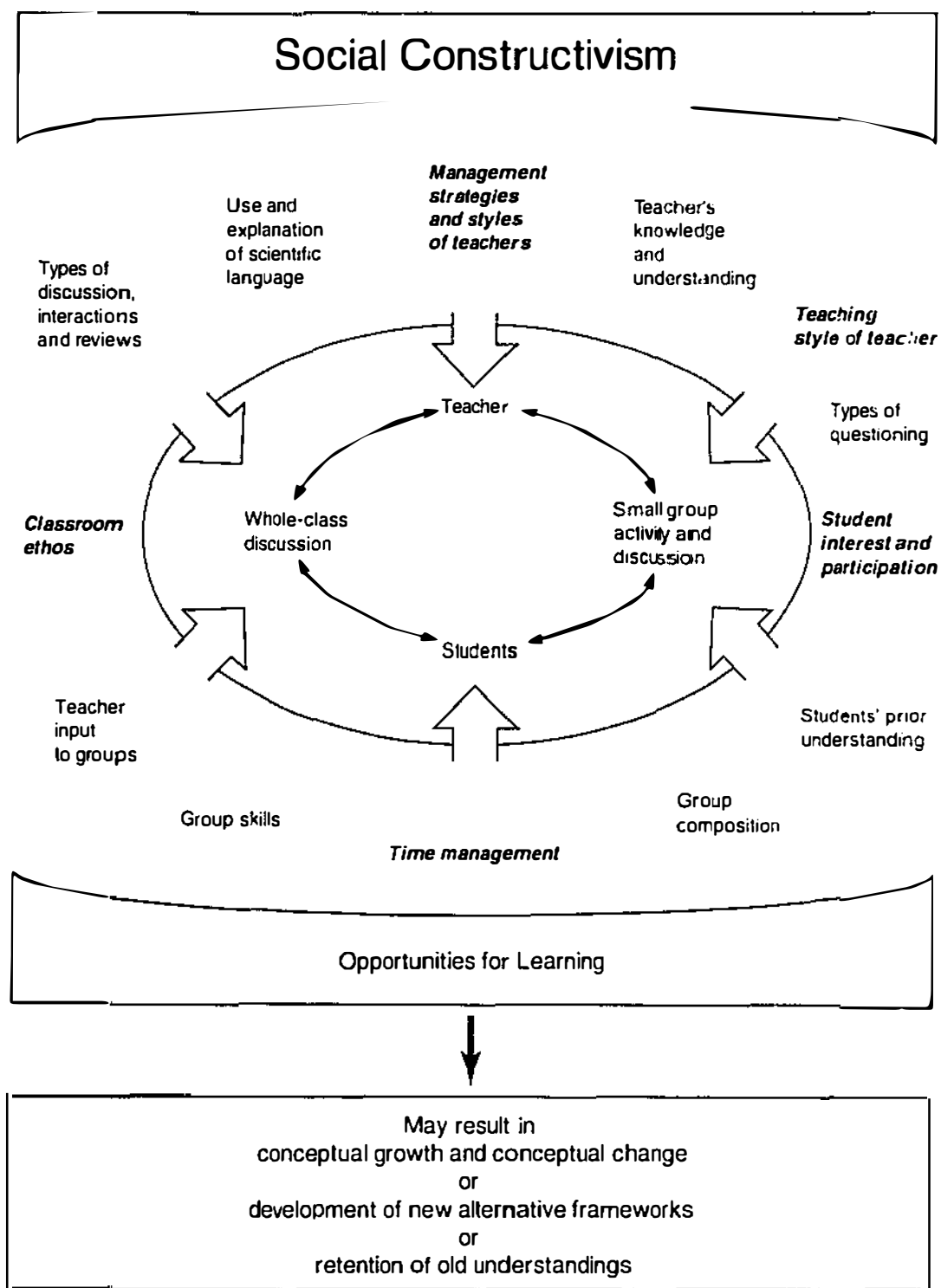
In this study, the level of group work skills was generally limited, although groups comprising cooperative students managed the activities and discussions reasonably well. However, although the teachers had used group work consistently, the skills of ensuring all members participated; skills of resolving interpersonal problems in groups; and skills of constructive discussion were limited. The notion that male students dominate the use of equipment (Kahle & Lakes, 1983; Whyte, 1984) was not supported by this study, but students of any gender dominated the use of equipment and limited the use by specific group members, who were also not involved in the group discussions. It was difficult to decide whether the non-participation was totally imposed by the group or whether the students withdrew from the activities and discussions. Kempa and Ayob (1991) argued that students were unlikely to learn if the non-participation was imposed by the group, but all three of the Focus Group students in this study who did not participate in activities and discussions made considerable gains in understanding.

Students who were allowed to progress at their own rate and who were given responsibility for their own progress, were more involved in the activities and were more likely to stay on task. Although there are many studies related to group work, this aspect of science lessons does not appear to have been investigated, although Roth (1995) considered that, in his study in secondary classrooms, the students were more on-task because of their ownership of the task. Ownership in the science lessons in this study was limited, but where an element of ownership was allowed by group management of the task, the students were more on-task.

The study demonstrated that the time allowed for activities in group work needs to be carefully monitored so that the students have enough time to complete the task but do not have the opportunity to be off-task for any length of time. When this happens, students are likely to lose the flow of the lesson.

Primary science lessons are a complex learning milieu and there are many teacher and student behaviours that impact on the learning that occurs. This study analysed in detail the different levels of discussion and activity and found that, even when the concepts had not been clearly explained by the teachers or students, students still managed to improve their understanding.

Summation



Note: Aspects generated by this study are in bold italic

Figure 10.2. Teaching and learning for conceptual growth and change: Aspects that may affect learning including those generated by this study

In Chapter 2, Figure 2.2 showed the aspects of lessons that could have an effect on the changes in understanding that might occur in primary science lessons. This study

has extended the understanding of some of these: but had also found other factors that will affect the learning that occurs (Figure 10.2).

The new factors demonstrated by this study that appear to have a major impact on learning are the classroom ethos, the management strategies and styles of the teacher; the teaching style of the teacher; the level of involvement of the students; and the level of responsibility and independence the students are allowed.

This Chapter has brought together all the data collected in the study. The next chapter looks at the limitation, conclusions and implication of these findings.

CHAPTER 11

Limitations, Conclusions and Implications

Limitations

This research involved case studies in a small number of classrooms with students of a limited age-range as participants and, as such, has limited generalisability. However, the amount of background information obtained about the schools, teachers, students and context of situation may allow readers to relate the findings to other situations.

The students in the second school were in their last term at primary school and their teachers stated that this was affecting their behaviours. This did not appear to affect the science lessons as most inappropriate behaviour appeared to be related to the teaching methods that were being used. Some data were not accessible because of recording difficulties, but the missing information could often be inferred from the context.

In each class, only the equivalent of four lessons and only one topic area were studied. Extending the length of the study, including other science topics and providing more opportunities for the students to apply their learning to other situations may have improved the learning and provided richer research data.

A delayed posttest would have provided data that would have added to the study, but this was not possible as most students were at the end of their last year at primary school and moved on to a range of high schools.

Conclusions

This section relates the findings of the study to the research questions. It initially discusses the secondary research questions and then relates the findings to the primary research question.

Secondary Research Questions

How does the teacher present the science topic and offer initial explanations and instructions for activity work?

The teacher's method of introducing the topic is strongly affected by his/her management and teaching styles. Overarching Assertion 3 suggests that, if behaviour management and task management are organised so that overt control mechanisms are

used less, the lesson will flow smoothly and students are more likely to stay on task with less teacher interruptions, and the time available for conceptual discussion will be increased. The study included classrooms that were strongly teacher-centred and teacher directed, and classrooms which allowed the students more responsibility. Where the classroom is teacher-centred, the teacher tends to give firm and specific instructions and ensures that the students know what they are expected to do, allowing little freedom of investigation or responsibility. S/he expects the students to follow the instructions and students who move away from this framework are likely to be brought back on-task quickly. This ensures that the activities are completed but this style of introduction does not encourage students to think about the activities or to extend their learning. In the less-teacher centred classroom, the students are given the instructions and are expected to follow them, with the teacher requiring the students to take responsibility for their tasks. However, students are still likely to be reprimanded when they have changed the investigation, although new discoveries are more likely to be positively evaluated and may be shared with the class. This style of introduction allows the students to think about the tasks, and more opportunities for learning occur.

Overarching Assertion 2, which suggests that when teachers do not use the curriculum materials as intended, the students will be disadvantaged unless the teacher has a very good understanding of the topic and is able to provide an alternative sequence of learning experiences that provide opportunities for developing the intended learning outcomes, also relates to this research question. The method of introducing the lesson was influenced by the teacher's teaching style with Mr Avery using an introduction that gave all the students, even those who had no knowledge of electric circuits, a starting point. Mr Carter used more open-ended tasks and presented challenges to the students which engaged their attention. In both situations, the changes to the curriculum did not affect the learning that would occur because both teachers had sufficient knowledge of the topic to make appropriate changes, and the changes only affected a small part of the lesson.

Overarching Assertion 4 argues that, when a teacher's understanding of the topic and his/her knowledge of alternative frameworks is restricted, this will affect the quality of explanations and discussion and limit the learning opportunities that are available to the students. Where the teacher's knowledge is limited, s/he will follow the curriculum materials, a positive move in that it results in the materials being used as designed. However, the teachers will not be able to add to the materials to increase the students'

interest or help those who are less knowledgeable. Where the teachers are more knowledgeable they are able to add more interest to the introduction, and may, like Mr Carter, consider aspects of the investigation that were not included in the lesson outlines such as safety. They are also able to adapt the lesson to fit their teaching style and the students' learning style. This may result in better learning as the students are learning in a more appropriate way.

How do the discussions that take place between students during group activity work and the way the activities are managed affect student participation and the opportunities for learning?

There are many influences on the interactions and activities that occur in groups. Overarching Assertion 7 argues that, where groups are cooperative and have an effective leader, they are likely to complete more tasks than uncooperative groups or those without a leader. It was apparent that the presence of a leader in a group had a positive effect on the discussions and in task management. The Focus Group in Mr Carter's class, which did not have a leader, had difficulty staying on-task, discussing cooperatively or completing tasks. The students in this group were unable to work together cohesively and illustrated the necessity for group membership to be planned carefully and changed if a group is dysfunctional. The improvement in understanding that occurred in this group was generally low. The groups that had leaders demonstrated some construction of understanding during their discussions, although their ideas were not necessarily correct. Some of these understandings were retained until the posttest although they would also have been reinforced by other teaching.

Although all the classes in the study had regular experience of group work, many students did not demonstrate good group work skills. Before a group can function efficiently, the members need to develop the appropriate group work skills, including those of cooperation, on-taskness and discussion (Overarching Assertion 8), and these skills were not apparent in some of the group work that occurred. Groups that do not have the skills to work cooperatively and engage all the students in the activities and discussion, and are unable to manage situations where conflict occurs, limit the discussion in the group and restrict the opportunities for learning. Mr Avery's Focus Group demonstrated good group work skills and their improvement in understanding was substantial, although they did also have the advantage of a competent teacher. Mr Carter's Focus Group lacked any group work skills with poor discussion and management of activities and this group demonstrated the least improvement in

understanding. In all the groups there were students who were not willing to listen to all the ideas that were presented and, because of the lower status of a group member, did not accept his/her scientific ideas. This disadvantaged some groups in some situations but, where the concept was later discussed in the whole-class discussion, any incorrect understandings were addressed.

Most of the discussion that occurs during group work is related to managing the task with a small amount of conceptual discussion occurring, usually when requested by the teacher. There is also some social talk, with this varying between students and groups, with some group members such as Ryan and Katy in Ms Brown's Focus Group, frequently engaging in social discussion, although the rest of the group were less likely to participate. In Mr Carter's Focus Group, the social discussion was a large component of the total interactions, with all the students involved although the composition of the group resulted in the interactions generally being quite negative.

Small group discussion when managing tasks may offer opportunities for learning and the construction of understanding, particularly when the practical task illustrates a concept such as the connecting points in a circuit. However, if, as happened in all the Focus Groups, one student is not included in the activity, s/he could be disadvantaged. In the study, three students who participated less than other students, both in the activities and the discussions, all made a substantial improvement in understanding indicating that passive and non-overt participation may not necessarily limit learning.

The use of worksheets with discussion points included can motivate and focus some discussion, but this only occurs if the students are following the worksheets, and are not being restricted by changes to the curriculum materials. Explanations and meanings may be constructed during group work, but this only occurred occasionally during the study. Generally, even when asked to discuss by the teacher, the discussion was limited. Group discussion may result in the development of unscientific understandings and, unless these are addressed at some point in the lesson, the students may retain these as learning outcomes.

Overarching Assertion 6 argues that, where teachers provide good explanations; science terms are clearly explained and used consistently; and student answers are summarised where necessary; students may develop better understanding and their explanations will use more scientific terms than when these conditions do not apply. In the study, the teachers' use of scientific terms relating to concepts had little effect on the

group discussion with no group using them frequently in the discussions. However, the teachers' use of terms varied with no teacher using all scientific terms consistently. In Mr Avery's Focus Group it appeared that Mr Avery's style of discussion and his expectations of fully justified answers may have influenced the way the responses and suggestions were made in the group, with students sometimes offering explanations for their statements, allowing the other group members an opportunity to accept their ideas and improve their understanding.

The classroom climate may have some effect on the discussion that occurs in groups. Overarching Assertion 1 argues that, in a supportive and friendly classroom, where the teachers demonstrate an interest in the students' ideas and discoveries, the students are more likely to become engaged in learning. A supportive classroom encourages the students to put forward their ideas and, if the classroom ethos carries over into the group work, the group members will respond positively. However, even when the classroom climate is less positive, if the group members have been chosen carefully and/or the students have good group work skills, the interactions and activities may still be productive.

Overarching Assertion 3 discusses behaviour and task management and the effect on lesson flow, student attention and conceptual discussion. Where students had responsibility for continuing the task in their groups without waiting for teacher instructions, they remained more motivated and were less likely to be off-task. Off-task behaviour would be likely to affect the learning as it would fragment the lesson.

The teacher's visits to groups also influence the interactions and development of understanding and this is discussed next.

How does the teacher interact with groups and how does this influence the teacher's and students' participation and opportunities for learning?

Teachers interact with the group members in the same style as they interact with the class and this has an effect on the willingness of the students to offer suggestions and ideas or to question the teacher's statements. Overarching Assertion 1 argues that, in a supportive and friendly classroom, where teachers show an interest in the students' ideas and discoveries, the students are more likely to become engaged in learning. Where the teacher is friendly, as Mr Avery and Mr Carter were, and demonstrate a willingness to listen to the students, the students are more likely to offer ideas that are unusual and to ask questions when they do not understand. This gives the teachers more opportunity to recognise students' ideas and facilitate the discussion to address any

unscientific understandings. Where the teacher is less relaxed with the students, as was Ms Brown, the students' answers are likely to be more restricted and they are less likely to question the teacher, restricting the opportunities the teacher has to recognise and address unscientific understandings.

In all the classes most teacher/group interactions were managerial, although there were less of these in Mr Carter's class than either of the others. All the teachers used a similar percentage of behaviour management utterances with the majority of the managerial utterances relating to the task, whether a practical activity or written. Overarching Assertion 3 discusses behaviour and task management and the effect on lesson flow, student attention and conceptual discussion. Generally, when teachers visited groups, the interactions were unlikely to distract the students from the task and usually helped solve problems. However, any conceptual discussion was often limited. Mr Carter was the only teacher who used much of his group visit time for conceptual discussion, allowing the students to manage more of the task themselves. He also engaged in the optimum method of helping students with practical tasks that was demonstrated in this study, which also helped the students develop understandings. When the students were having difficulty with the practical activity, he asked questions which directed the students to the problem and gave them the opportunity of solving it. Both Mr Avery and Ms Brown's task management offered students fewer opportunities to develop understandings with Mr Avery often correcting the circuit whilst explaining what he was doing. For effective learning, students need hands-on experience and, although watching Mr Avery correcting the circuits was useful, it was less effective than if the students did the work. Overarching Assertion 10 argues that, when students are having difficulties either with tasks or group skills, teachers should use ways of helping them that will enable them to improve their skills and understandings both of the tasks and of group management.

The teacher's knowledge affects the interactions, and Overarching Assertion 4 argues that if a teacher's understanding of the topic and his/her knowledge of alternative frameworks is restricted, the quality of the explanations and discussion, and the learning opportunities available to the student, will be limited. This may result in teachers either not recognising the unscientific understandings that students have, or the teachers may, if they have alternative frameworks themselves, reinforce the unscientific beliefs of the students. Both these scenarios occurred in Mr Carter's class. If the understandings are not discussed later with the whole class, the students may be left with unscientific

understandings. The whole-class discussion may generate new ideas which may be recognised by students as more scientifically valid than their own, even if the teacher's knowledge is not good.

Overarching Assertion 6 argues that teachers' use of explanations and science vocabulary may affect the students' explanations and use of science vocabulary. In all the classes the teachers' use of scientific terminology was limited when they visited the groups and there were limited examples of the teachers encouraging good explanations and use of vocabulary.

Overarching Assertion 9 suggests that, where the group members do not have the skills for group work, the teacher's attendance at the group improves the attentiveness of students and the quality of the discussion resulting in more opportunities for learning. This was particularly apparent in Mr Carter's class where the Focus Group were unable to work constructively without teacher attention.

In whole-class settings, how does the teacher manage the discussion to bring together the reports of group discussions and develop scientific understandings, and what factors influence the students' participation and the opportunities for learning?

When the classroom ethos was friendly and supportive, the level of participation in whole-class discussions was high, with students offering suggestions and ideas and questioning information given by the teacher (Overarching Assertion 1). This was very obvious in Mr Avery's classroom and sometimes occurred in Mr Carter's lessons.

The management strategies that teachers used had a major impact on the learning that was likely to occur. Some behaviour management strategies were intrusive and fragmented the lesson, giving the students less opportunity to follow the sequence of the lesson, whereas others allowed the lesson flow to continue and brought reprimanded students back on-task without disrupting the lesson. Overarching Assertion 3 considers that, when behaviour and task management are organised so that overt control mechanisms are used less, this will have an effect on the lesson flow, with students more on-task and more time for conceptual discussion.

The ways the teachers managed the discussion varied. Ms Brown tended to keep a tight control over the direction and content of the discussion, allowing no discussion outside her parameters, limiting the students' interest and their opportunities for learning. Teachers sometimes accept and use student questions outside of the prescribed lesson plan to extend students' understanding, but this only occurs when the teacher has

the knowledge to respond, and is willing to use class time to discuss other concepts. The lessons in the study were fairly structured, but there does seem to be, with some teachers, still a curriculum driven mode of teaching which insists that the curriculum materials are closely followed. Both Mr Avery and Mr Carter stepped outside the framework of the curriculum in the study on several occasions and allowed a variety of extensions to occur.

When a teacher's understanding of the topic and his/her knowledge of alternative frameworks is restricted, the quality of the explanations and discussion, and the learning opportunities available to the student, will be limited (Overarching Assertion 4). If the teachers have alternative frameworks, they may reinforce the unscientific beliefs of the students, as occurred in Mr Carter's class. Teachers who are more aware of the range of understandings that students have are more likely to use open questions in a variety of situations to generate discussion and ideas. Ideally, they then need to direct the discussion so that the students generate an acceptable scientific understanding. This occurred in Mr Avery's class and sometimes in Mr Carter's. Often, as occurred in Ms Brown's class, the discussion is limited and, once the teacher accepts an answer as correct, the students are expected to accept this, a strategy which is unlikely to produce a long term change in understanding. The shortened discussion limits the richness of explanations and changes in understanding.

The discussion style of the class, teachers and students, will influence the amount of learning that can occur. Overarching Assertion 5 argues that the strategies used by teachers in discussions have an effect on the engagement or otherwise of the students; the knowledge the teacher gains of student understanding; the explanations that are constructed; and the opportunities for student learning. Where teachers accept limited answers from the students they are less likely to recognise the understandings that the students have and the other class members are provided with only limited explanations from which they can develop understandings. If students offer reasons for their answers, or justify them, as was the case in two classes in the study, they allow the teacher more opportunity to recognise the thinking that has produced the answer and address any errors, and richer explanations are provided for their class mates to consider.

It is possible that, where teachers provide good explanations; science terms are clearly explained and used consistently; and student answers are summarised where necessary; students may develop better understanding and their explanations will use

more scientific terms than when these conditions do not apply (Overarching Assertion 6). During the whole-class discussions the quality of explanations and use of scientific terms varied with Mr Avery, offering the most scientific explanations and showing more consistency in his use of terms. His students developed a better understanding of science vocabulary than those from the other groups, but their use of terms in discussions was limited. The understanding of scientific vocabulary was more restricted in the other two classes.

What understandings of science concepts do students develop and how are these embedded in their language?

The understandings that students develop reflect the knowledge of the teacher; the amount of discussion related to that topic; the emphasis that was put on the concept by the teacher; the ways in which understanding of the concepts was constructed; and the discussions that occurred in the groups. However, as indicated by Overarching Assertion 11, some student learning occurred even when the process was not obvious and the concepts were either not clearly covered or the student was inattentive. Students are more likely to develop an understanding of tangible, practical aspects such as the methods of constructing a circuit rather than the more abstract concepts that are not visible, such as the direction of current flow, but this is still related to the amount of discussion of the concept and the emphasis put on the concept by the teacher.

Propositions where the development of understanding by the students was limited were: Proposition 2 (the amount of electric current in any part of a circuit will be the same) and Proposition 4 (when a circuit is connected and a globe is lit there is an electric current through all parts of the circuit including the battery) which were poorly covered by all teachers; and Proposition 5 (electric current travels in one direction through a circuit) which was poorly covered by Ms Brown, and Mr Carter had an alternative understanding which he taught. The propositions where the most learning occurred were: Proposition 1 (if components have not been connected in a complete circuit there is no electric current in any component) in both Mr Avery and Mr Carter's class which was covered well in both classes; Proposition 6 (some materials allow electricity to flow through them) in all classes, although the improvement was more substantial in Ms Brown and Mr Carter's classes, both of whom used interesting ways of presenting the topic; Proposition 7 (which related to series circuits and the relationship of globe and battery voltage) in all classes; and, in Mr Avery's class, Proposition 3 (joins in a circuit).

Overarching Assertion 6 stated that where teachers provide good explanations; science terms are clearly explained and used consistently; and student answers are summarised where necessary; students may develop better understanding and their explanations will use more scientific terms than when these conditions do not apply. There was little science language used by students with the few science terms used tending to be those related to tangible objects such as battery and globe but, as indicated previously, the use of scientific language by the teachers was inconsistent.

Primary Research Question

How do interactions and discussions in primary science classrooms and the language used by teachers and students affect the meanings that students construct for science concepts?

All interactions in primary science lessons are affected by the complex environment of the classroom. They are affected by the classroom ethos; the curriculum materials and their use; the level of the teacher's knowledge of the topic and alternative frameworks; the types of discussion and questioning that occur and the strategies that are used to assist in developing understandings; and the student behaviours and teacher behaviour management techniques. When the interactions occur in groups they are also affected by the cohesiveness of the group members; the level of group skills; the level of discussion; the group members' level of participation; and the roles that the students and the teachers take within group activities. The interactions affect the explanations and understandings that students develop, but the influences on the interactions, such as behaviours and management strategies, have a greater impact on them. The students' participated with more enthusiasm and interest in classes where the teachers were friendly and interested in the students and their work and questions. Where teachers are knowledgeable and use animated and interesting discussion techniques, with a wide range of demonstrations and methods of presenting information, the students are more involved and their level of understanding improved, as happened in Mr Avery's class. The teacher's behaviour and task management techniques had a major impact on the students' level of attention and the smooth sequencing of the lessons, with intrusive behaviour management disrupting the class.

The scientific language used by the teachers had little impact on the students' use of science terms. Mr Avery used more scientific terms than the other teachers and was generally more consistent in his language use and there was a slightly higher level

of use in the Focus Group from Mr Avery's class. Generally the scientific terms used by students were not those that referred to concepts.

The meanings that students construct for science concepts are affected by the classroom interactions and to a lesser extent by the scientific language, but these, in turn, are affected by all the factors that make up the complex milieu of a primary classroom.

Implications

Overview

The implications generated by this study are outlined in this section. Initially, the overarching assertions are used to generate implications for teaching and curriculum development, and, in this section, some overarching assertions have been grouped as the subsequent implications relate to more than one assertion. Overarching Assertion 3 has been used in two places in this discussion, once relating to whole-class work and once to group work. The discussion then looks at the implications for research, suggesting some areas that merit further investigation.

Implications for Teaching and Curriculum Development

Overarching Assertion 1: When the classroom is supportive and friendly and the teachers demonstrate an interest in the students' ideas and discoveries, the students are more likely to become engaged in learning.

The study demonstrated the difference in student participation in supportive, friendly classrooms compared to less supportive classrooms. To encourage participation, teachers need to be aware of the way their behaviour affects the learning process and generate a friendly classroom environment, where the students feel secure and are therefore willing to offer a variety of ideas knowing that they will not be criticised for not giving a completely acceptable answer or explanation. Both the teacher and other students need to be supportive of unusual ideas.

The classrooms where students were willing to offer ideas and demonstrate their models or understandings were also the ones where, when unsolicited student input occurred, the teachers offered praise and encouragement and treated the students' discoveries and input as important. Teachers need to realise that students require praise and encouragement to stay enthusiastic about tasks, and must also recognise that unsolicited information from the students often presents insights into student understandings. These insights also occur when a student queries something that has

occurred in the lesson, during a discussion or activity. These queries may demonstrate a lack of understanding and need for help, but may not be recognised as such and teachers need to be alert to these situations.

Overarching Assertion 2: When teachers do not use the curriculum materials as intended, the students will be disadvantaged unless the teacher has a very good understanding of the topic and is able to provide an alternative sequence of learning experiences that provide opportunities for developing the intended learning outcomes.

None of the teachers in the study used the curriculum materials as intended resulting in some activities not being included and the appropriate learning not occurring, and other materials being taught inaccurately. The strategies and discussion that occurred were often dependent on the teacher's level of understanding of the topic and of alternative frameworks. The lesson outlines provided to teachers were based on curriculum materials that were available at the time and were changed by some teachers so that the materials would better fit their teaching style, sometimes limiting the learning that could occur. With the changes in focus of the Western Australian education system towards outcomes based education with a more student-centred approach, and the freeing-up of the curriculum so that teachers are able to choose topics and teaching styles that suit their classes, changes need to be made to provide more flexible curriculum materials that support a range of teaching and learning styles. Two of the teachers in the study had a more student-centred approach, with one choosing to change the activities into more open-ended activities, one of the approaches which has now been suggested by the new Western Australian Curriculum Framework (Curriculum Council, 1998). This study was conducted before the changes were instigated by the Department of Education of Western Australia but it does indicate limitations in the materials which, if addressed, would help teachers implement some of the changes. New curriculum materials are available but still tend to have limitations. Curriculum writers need to consider the range of teaching styles that primary teachers use to cater for the range of abilities and the learning styles of students in their classes and materials need to be written to cater for differing styles of teaching. It would be helpful if curriculum materials were designed to allow the teachers freedom to adapt them to their teaching styles and to the needs of their classes, whilst maintaining the integrity of the materials.

Curriculum materials provided for teachers, as in this study, may not be well-designed for primary teachers who have limited science understanding or difficulties teaching science. They need to include an overview of the topic which shows relationships between the activities and the intended learning outcomes and indicates those which are essential for the intended learning to occur. The materials need a range of discussion points and demonstrations that could be used and, because there is a need for frequent relevant activities to produce conceptual change, a range of activities and extensions. The teacher notes need to be concise, as primary teachers have limited lesson preparation time and they need to be couched in language that teachers without a science background can understand and include a glossary of terms. Teachers are often still unaware of the extent of alternative frameworks that students may hold and information about these should be provided. Professional development experiences are needed to help teachers understand these issues, but they must be designed to attract the teachers who are not enthusiastic about teaching science. It would be also useful if there were materials available which would allow the students to work on the activities without excessive direction by the teachers, where they can progress at their own rate.

Overarching Assertion 3: If behaviour management and task management are organised so that overt control mechanisms are used less, the lesson will flow smoothly and students are more likely to stay on task with less teacher interruptions, and the time available for conceptual discussion will be increased.

The range of behaviour management strategies used by the teachers in the study offered an insight into the ways in which the discussion could be adversely affected when they were intrusive and teachers need to be aware of this. There are two aspects to behaviour management. There are the strategies themselves, and there is the organisation of the classroom and lessons so that their use is minimised. Where management strategies are needed, they should be used in a way that does not fragment the discussion and distract the students from the discussion or activity. A major whole-class behaviour problem may need discussion outside of the science lesson as students need to be involved in the solutions of problems so that they have ownership of the solution and are more likely to respect it.

Teachers need to be aware of the likely inattentiveness of students and ensure that discussion times are appropriately organised so that the students are not distracted by items on their desks. They should use a range of strategies to engage the students; and ensure the discussions are interesting and animated.

Overarching Assertion 4: When a teacher's understanding of the topic and his/her knowledge of alternative frameworks is restricted, this will affect the quality of explanations and discussion and limit the learning opportunities that are available to the students.

Overarching Assertion 5: The strategies that teachers use in discussions have an effect on the engagement or otherwise of the students; the knowledge the teacher gains of student understanding; the explanations that are constructed; and the opportunities for student learning.

Student engagement in whole-class discussions is essential if scientific changes in understanding are to occur, and the study indicated that the range of strategies a teacher used, and the style of the discussion, had an impact on the attention the students paid to the whole-class discussion.

Teachers need to improve the quality of class discussions that occur by improving teacher and student input. To hold the students' interest, discussion needs to be lively and interesting with many participants. The teachers need to be willing to accept a variety of answers and manage discussions so that the students are involved in constructing understanding and the generation of a scientific view. This would include teachers learning to use open questions effectively, and evaluating student responses in an appropriate way. If the students are generating ideas that will be tested, or the correct idea is to be disseminated later, the evaluation needs to be neutral. In other situations it may be necessary to state whether the response is correct or not and explain the reasons. Teachers also need to be able to summarise the points of a discussion to bring the ideas together and make links with the students' understandings. Links also need to be made through regular reviews of the work covered, and the use of a concept map or a similar strategy would show the understandings developed and could be built on each week, but links also need to be made across the curriculum so that science is not seen in isolation.

Discussion and questioning are probably the areas in which it is hardest for teachers to recognise their needs and are also areas where professional development opportunities might be limited. These are, however, areas that need attention.

Teachers also need to make use of the information and activities suggested in the curriculum materials and, if they have the knowledge, expand on these to provide more learning experiences for the students. They should also try to use a variety of strategies and, even if their science knowledge is limited, they should have the teaching experience to be able to provide activities and discussions that generate information in a

variety of ways. Teachers should be aware of their limitations and choose resources that increase their content knowledge and facilitate the students' search for scientific answers, but should also improve their science knowledge so that they are able to recognise opportunities for learning when they occur. Teachers require professional development related to science which is not threatening to the teacher who is not enthusiastic about teaching science.

Overarching Assertion 6: Where teachers provide good explanations; science terms are clearly explained and used consistently; and student answers are summarised where necessary; students may develop better understanding and their explanations will use more scientific terms than where these conditions do not apply.

The use of scientific terms and explanations by teachers and students in this study was generally disappointing. It indicates that many teachers find it difficult to use these terms consistently and correctly and explain their meanings. Teachers should use science terms correctly and consistently themselves, modelling their meaning and use, and encourage the students to provide good explanations and use the correct terminology. They also need to provide opportunities for students to use science terms appropriately.

The use of science terms should be integrated across the curriculum so that the students have an opportunity to use them in different situations, eg. spelling, dictionary skills. This might enable them to recognise the range of meanings for terms and identify the science meaning.

If, as suggested, curriculum materials include glossaries of terms and clear explanations of their meanings, primary teachers with limited science knowledge would have a resource that would help alleviate their limited use of science language.

Overarching Assertion 7: Where groups are cooperative and have an effective leader, they are likely to complete more tasks than groups that are uncooperative and lack effective leadership.

Overarching Assertion 8: Before a group can function efficiently, the members need to develop the appropriate group work skills including those of cooperation, on-taskness and discussion.

Group work is frequently used in science lessons and is a focus of the new initiatives from the Department of Education of Western Australian. Teachers need to ensure that the students in a group are able to work cooperatively without major

personality clashes, and need to promote a positive and supportive classroom climate providing a model for group interactions. Students often do not have the level of skills required to participate effectively in groups and, hence group work is used, it is essential that group work skills are taught and then reviewed each time group work occurs. Students need to accept the responsibility for task completion when working in groups, and need strategies which will assist them. They should be aware of the roles that they need to take in group work, and should ensure all group members are involved in the activities and discussion. They also need to understand how a discussion should be conducted, how information should be communicated and how to manage differences of opinion during discussions.

This is another area where teachers require professional development so that suitable skills development programs are implemented in all schools.

Overarching Assertion 3: If behaviour management and task management are organised so that overt control mechanisms are used less, the lesson will flow smoothly and students are more likely to stay on task with less teacher interruptions, and the time available for conceptual discussion will be increased.

Overarching Assertion 9: Where the group members do not have the skills for group work, the teacher's attendance at the group improves the attentiveness of students and the quality of the discussion.

Overarching Assertion 10: When students are having difficulties either with tasks or with group skills, teachers should use ways of helping them that will improve their skills and understandings both of the task and group management.

Implications for teaching

The teachers in the study used their visits to groups in a variety of ways and for a variety of purposes producing a range of learning outcomes. Teacher visits to groups need to be managed carefully to ensure that they are effective and useful. If students are involved in practical activities and are having difficulties, teachers should have strategies available which will facilitate students' problem solving rather than giving them the solution. Teachers should facilitate discussion rather than managing it, an ability which should offer the students a role model for discussion; and facilitate the students' efforts to solve interpersonal problems. Teachers need to hand over the responsibility for group work to the students, and take on the role of facilitator rather than manager, but, because of the positive effects that effective teacher-group visits produce, they need to organise their time so that all groups are visited during group

activity time. These strategies may require longer group work time and result in more time being required for this type of lesson.

Teachers, as part of their role when visiting groups, should facilitate the use of good group work skills, but may also need to facilitate problem solving within the group. However, the students must be involved in decision making when there are problems so that they have ownership of the solution. If the teacher needs to use behaviour management strategies, they should be used in a way that does not disrupt the learning that is occurring in the group. Teachers also need to manage group discussion time perceptively, so that the time is of a suitable length to effect productive discussion, but not so long that the students become off-task.

Overarching Assertion 11: Student learning may occur even when the process is not obvious.

Students in this study showed evidence of learning even when it would appear from the data that there were no overt opportunities for learning. This indicates that learning can occur in any circumstance and that teachers need to use a variety of situations and methods to engage students in learning. The whole-class discussions should be an important source of information for the students, but to increase the opportunities that students have for learning, the same phenomena and ideas need to be presented in a variety of ways at different times. There should be frequent opportunities for group discussion or discussion between students, with teacher input to ensure that the understandings constructed by the students are valid. The practical activities should be designed so that discussions and understandings can be generated from these.

Implications for Research

This study has indicated the value of case study styles of research that reveal the number, complexity and subtlety of factors influencing learning. To further develop the findings of this study, research would be useful in a variety of areas. Intervention studies are needed to ascertain whether training teachers to use more effective whole-class and teacher-small group discussion strategies can improve student learning. Of particular interest would be investigations into changes from managing discussion to facilitating discussion, and encouraging students to elaborate on their answers. Investigation into the management, both reactive and proactive, of student behaviours would also assist the management of discussions and may improve learning outcomes. A further intervention study needs to investigate whether training students in cooperative learning

skills such as adopting appropriate group roles and managing conflict within group activities would not only improve group work but also improve learning.

More information is also needed about how learning occurs in lessons. One area which would benefit from further investigation is the learning that is demonstrated by non-participant or passive students, particularly in group work, but there also needs to be research into the sources of student learning, particularly when it is unclear how the learning occurred.

Research is also needed into the curriculum needs of primary teachers. It is apparent that changes may be needed in curriculum materials to cater for the range of teaching and learning styles that occur in primary classrooms and primary teachers should have the opportunity to have input into the development of these.

Linking to curriculum needs is the necessity for relevant, non-threatening professional development in science and teaching science. Teachers who are hesitant about teaching science often are also unwilling to attend professional development in science. Research is needed to ascertain the type of professional development that they might be willing to attend.

In Conclusion

The findings of this study have produced challenges for both curriculum writers and teachers and it would be likely that many of these findings would be reflected in other learning areas, as they are not always specific to science. The in-depth analysis of classroom life has provided some useful insights into the myriad influences that affect teaching and learning in primary science lessons and has demonstrated how opportunities for learning can be enhanced or negated by these influences. The challenges in this study need to be met to improve the learning opportunities that occur in primary science lessons.

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APPENDIX 1 **QUESTIONNAIRE: TEACHER BACKGROUND INFORMATION**

Teacher's name _____

TEACHING EXPERIENCE:

How long have you been teaching primary school? _____

How long have you been teaching year 7? _____

How long have you been teaching year 7 science? _____

How many primary schools have you taught at? State _____

Private _____

What year levels have you taught? _____

HIGH SCHOOL

What science did you do at high school?

<u>Type of science</u>	<u>To what year level</u>
General science	8 9 10 11 12
Physics	8 9 10 11 12
Chemistry	8 9 10 11 12
Biology	8 9 10 11 12
Other (please indicate type)	8 9 10 11 12

Teaching Diploma or Bachelor of Arts (Education):

When you did your Diploma or B.A. did you

Only take the core units in science Yes/No

Take additional electives in science Yes/No

If you can remember write down the type of areas your electives covered.

FURTHER UNIVERSITY STUDY

If you have completed any other studies at university or college did you take any science units. If so can you please list them or the areas they covered.

<u>Degree</u>	<u>Units studied</u>
<hr/>	<hr/>
	<hr/>
	<hr/>
<hr/>	<hr/>
	<hr/>
	<hr/>

Other study:

Have you attended any seminars or workshops related to science teaching Yes/no

If so, can you please give as much information about them as you can:

<u>Organised by</u>	<u>Topic</u>	<u>Any other information</u>
<hr/>	<hr/>	<hr/>
<hr/>	<hr/>	<hr/>
<hr/>	<hr/>	<hr/>
<hr/>	<hr/>	<hr/>

List any other experiences you may have had relating to science education which might have had an impact on your science teaching:

<hr/>
<hr/>
<hr/>

APPENDIX 2
SEMI-STRUCTURED INTERVIEW QUESTIONS FOR TEACHER
INTERVIEWS

How often do you teach science?

How long are the periods?

Are there any interruptions, e.g. staff meetings, assemblies

What topics do you teach?

What topics have you taught so far this year?

What topics would you plan on teaching for the rest of this year?

What did you teach last year?

Do you have set topics or do they develop from things that have happened or students' interests?

How do you think the students in your class develop science understandings?

What things do you do that might help the students to develop their understandings?

How good do you think the understandings are that they develop?

How do you structure your lessons?

Do the students work individually, with partners or in groups?

Do they do activities or do you demonstrate?

What sort of activities might the students do?

Do you find hands-on activities a problem in any way?

- behaviour
- equipment
- clearing up

How do you feel about children talking during science?

What sort of things might they discuss?

What other talk goes on in the science classroom?

- instructions
- whole class discussion
- children asking questions
- what type of questions are they likely to ask

How do you think students feel about science lessons?

Do you feel that science is an important part of the curriculum?

Does science ever creep into other areas of teaching?

APPENDIX 3
DIAGRAMS SUPPLIED WITH LESSON OUTLINES

DIAGRAM 4

SIMPLE ELECTRIC CIRCUIT

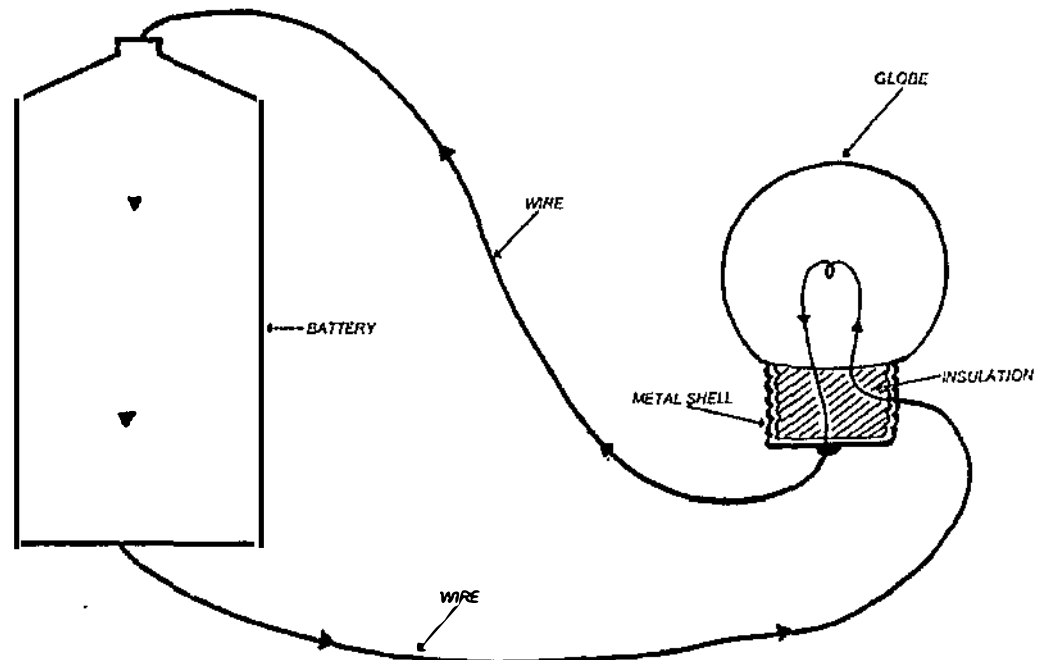
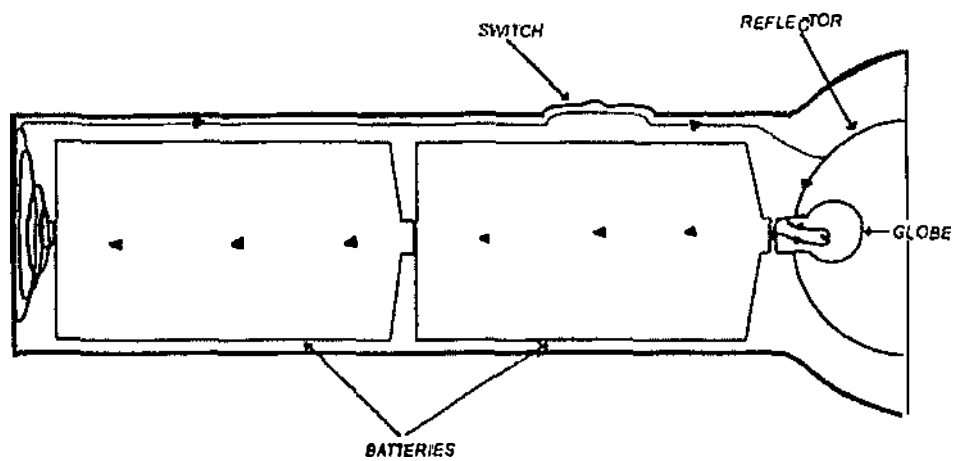


DIAGRAM 5

TORCH CIRCUIT



APPENDIX 4
PRE AND POSTTEST

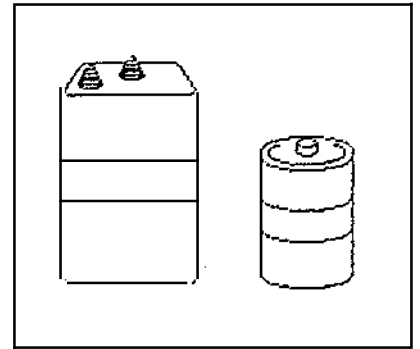
1.

Here are two batteries that have not yet been used. Is there an electric current in the batteries?

Yes

No

Explain why you think that



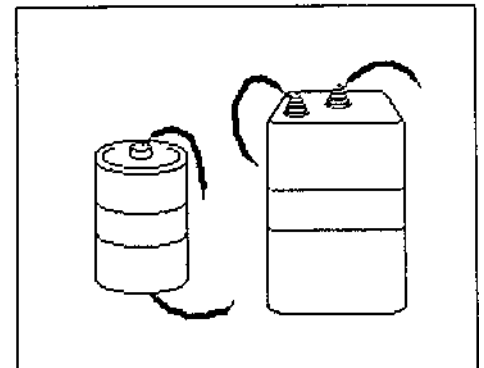
2.

This time the batteries have wires attached. Is there any electric current in the battery now?

Yes

No

Explain why you think that.



3.

Is there any electric current in the wires?

Yes

No

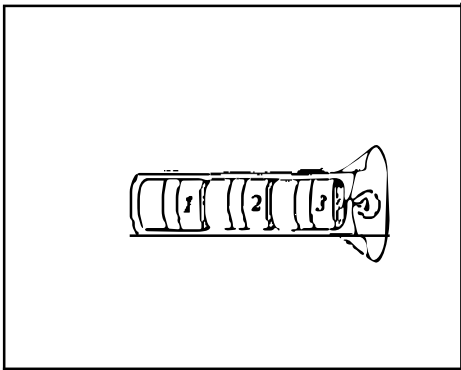
Explain why you think that.

4.

A torch has three 1.5v batteries in it as shown in the picture. The torch is switched on and the globe is glowing. Do you think there an electric current through the batteries?

Yes No

Explain why you think that



5.

Five students have all suggested different ideas about the electric current through the batteries. Circle the idea you think is best.

- (a) Battery number 1 will have the most electric current
- (b) Battery number 2 will have the most electric current
- (c) Battery number 3 will have the most electric current
- (d) Batteries numbered 1 and 3 will have more electric current than number 2
- (e) All batteries will have the same amount of electric current

Explain why you chose the answer that you did.

6.

The torch normally has a 4.5v globe. What would happen if you put a 1.3v globe in the torch?

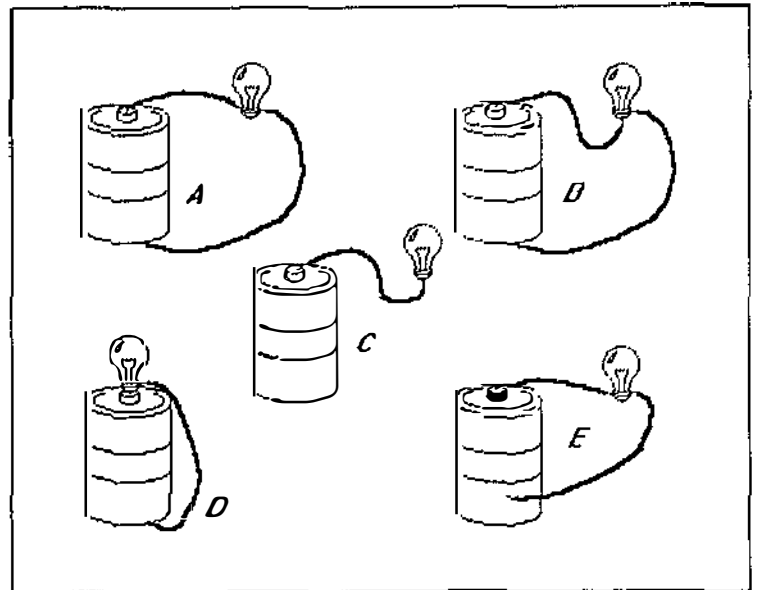
Explain why you think that will happen.

What would happen if you put a 6v globe in the torch?

Explain why you think that will happen.

7.

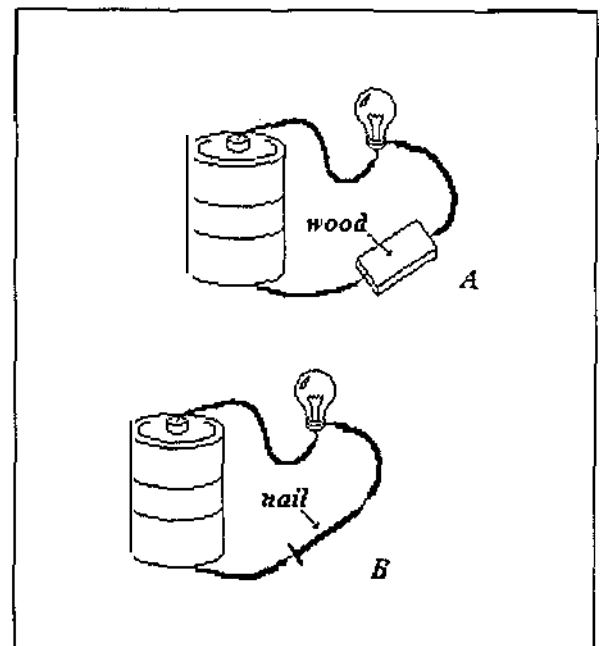
These are ordinary torch batteries that have been connected in different ways to a torch globe. Circle the pictures where you think the globe will light. Explain why the circuits you chose will light up.



Why won't the globes in the other circuits light?

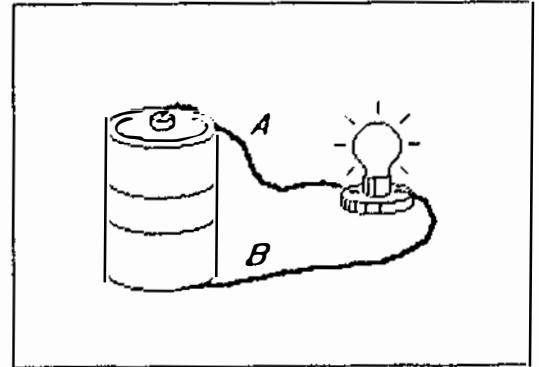
8.

Here are some more electrical circuits. Circle the one(s) you think will light the globe. Why do you think the circuits will or will not light?



9.

A battery is connected to a torch globe as shown. The globe is glowing and there is some electrical current flowing through the wires. Put some arrows on the picture to show which direction you think the electrical current is flowing through the wires.



Explain why you think the current will flow like that.

10.

Here is a series of statements about the amount of current flowing through the wires in the picture for number 9. Circle the one that you think is closest to being right.

- (a) There is no electric current in wire B
- (b) There is some electric current in wire B but less than in wire A
- (c) There is the same amount of electric current in wire A as in wire B
- (d) There is more electric current in wire B
- (e) There is no electric current in wire A

Explain why you chose the answer that you did

11.

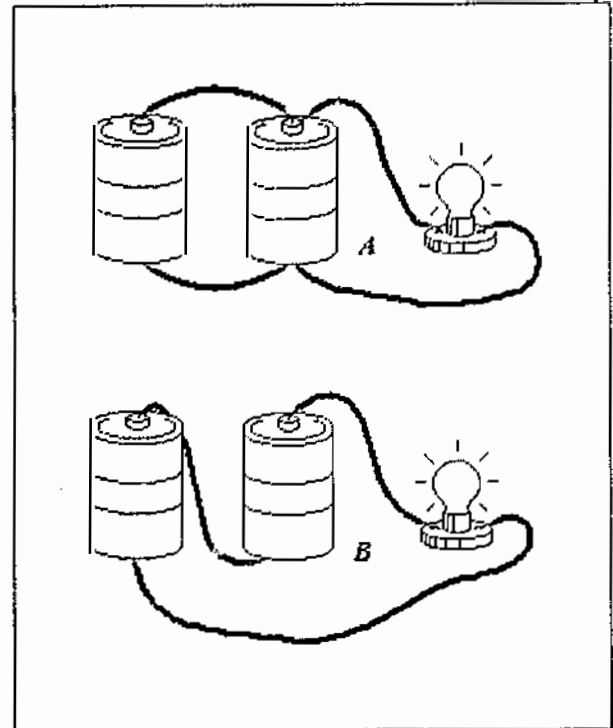
Do you think there is any electric current in the battery? _____

Explain why you think that.

12.

Which of the circuits in this picture would make the light globe glow brightest?

Why do you think your choice will be brightest?



13.

Which of the circuits in the picture for question 12 would allow the globe to light for the longer time?

Why do you think your choice will last longer?

APPENDIX 5

SEMI-STRUCTURED INTERVIEW QUESTIONS USING INTERVIEW- ABOUT-INSTANCE CARDS

Note: The questions are in the same order as the test. The pictures are the same as the test pictures apart from the questions related to globes in series and parallel.

1. Unused Batteries

Here are two batteries that have not been used yet. Is there any electric current in the batteries? What makes you say that?

2. Batteries with wires attached

This time we have the same batteries but they have some wires attached. Is there any current in the battery this time? What makes you say that?

3. Is there any current in the wires? What makes you say that?

4. Torch

A torch has three 1.5V batteries in it as shown in the picture. The torch is switched on and the globe is glowing. Do you think there is an electric current through the batteries?

What makes you say that?

5. Five students have all suggested different ideas about the electric current through the batteries. Which one of these ideas do you think is best?

- (a) Battery number 1 will have the most electric current
- (b) Battery number 2 will have the most electric current
- (c) Battery number 3 will have the most electric current
- (d) Batteries numbered 1 and 3 will have more electric current than number 2
- (e) All batteries will have the same amount of electric current

What made you choose that answer?

6a. The torch normally has a 4.5V globe. What would happen if you put in a 1.3V globe? Why do you think that will happen?

6b. What would happen if you put a 6V globe in? Why do you think that would happen?

7. Variety of circuits

These are ordinary torch batteries that have been connected in various ways to torch globes. In which of these pictures is the globe likely to light up. Why will the circuits you chose light up? Why won't the globes in the other circuit light up?

8. Circuits with nail and wood

Somebody built these circuits trying to work out which ones would light and which ones wouldn't. Do you think any of them would work? Which ones? Why do you think the others wouldn't work

*or "Why don't you think they will work?

9. Circuit with lit light globe

A battery is connected to the torch globe as shown. This time the globe is lit up and there is electrical current flowing through the wires. Show me on the picture which way you think the electrical current is flowing.

Explain why you said that.

10. Here is a series of statements about the amount of current flowing through the wires:

- (a) There is no electric current in wire B
- (b) There is some electric current in wire B but less than in wire A
- (c) There is the same electric current in wire A as in wire B
- (d) There is more electric current in wire B
- (e) There is no electric current in wire A

Why did you choose that answer?

11. Do you think there is any electric current in the battery? What makes you say that?

Batteries in parallel and in series

12. Which of these circuits would make the globe brightest? Why do you think that one will be brightest?

13. Which would allow the light to remain lit for longest? Why do you think that one will stay lit for longest?

Globes in parallel and series

14. Which circuit would have the brightest globes. Why do you think that one will have the brightest globes?

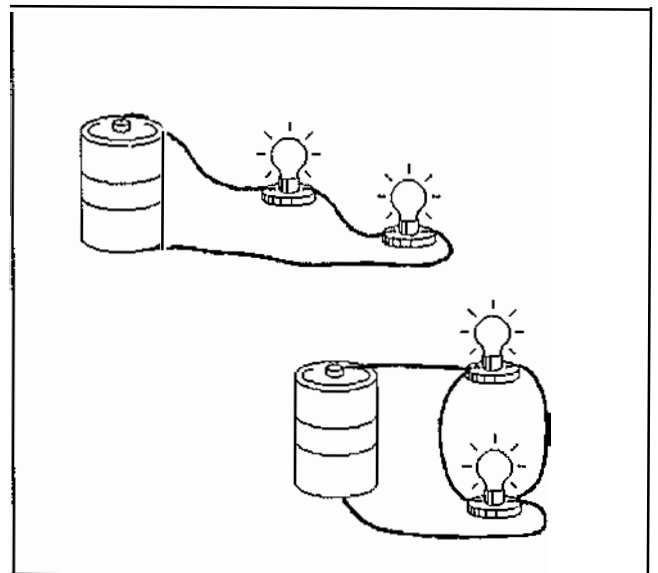


Diagram for Question 14

APPENDIX 6

SAMPLE ANSWERS AND SCORES FOR PRE AND POSTTESTS

Note: Where the score given was zero, the answer demonstrated no understanding.

Question	Score	Sample Answer
1. Here are two batteries that have not yet been used. Is there an electric current in the batteries? Explain why you think that.	3	The batteries have to be in a circuit to have a current
	2	You need to join the batteries together with a wire or something like alligator clips to get an electric current
	1	It has no wire and/or globe
2. This time the batteries have wires attached. Is there any electric current in the battery now? Explain why you think that.	3	It is not a complete circuit
	2	The batteries are not attached to anything
	1	It's not leading to anything
3. Is there any electric current in the wires? Explain why you think that.	3	They're not forming a circuit and do not connect with anything else
	2	Nothing is joining the wires
	1	They aren't connected to anything
4. A torch has three 1.5v batteries in it as shown in the picture. The torch is switched on and the globe is glowing. Is there a current through the batteries? Explain why you think that.	3	They form a circuit and the electric current can flow negative to positive
	2	It flows through the batteries and to the globe
	1	The batteries are joined and that makes a current
5. Five students have all suggested different ideas about the electric current through the batteries. Circle the idea you think is best. (a) Battery number 1 will have the most electric current. (b) Battery number 2 will have the most electric current. (c) Battery number 3 will have the most electric current. (d) Batteries numbered 1 and 3 will have more electric current than number 2. (e) All batteries will have the same amount of electric current. Explain why you chose the answer that you did.	3	As current is going into battery 2 from battery one and then battery 2 pushes out the same amount of electricity that just came into it
	2	The electricity doesn't stay in the batteries it moves on continuing around the circuits
	1	All the batteries will have the same amount of current because they are all joined together
6a. The torch normally has a 4.5v globe. What would happen if you put a 1.3v globe in the torch? Explain why you think that will happen.	3	The globe would blow because the amount of volts are too high for the globe
	2	It would blow because there is too much electricity in it
	1	You have three batteries
6b. What would happen if you put a 6v globe in the torch? Explain why you think that will happen.	3	There isn't enough volts in the three 1.5 volt batteries to light the 6 volt globe to its full brightness
	2	There wouldn't be enough power for the globe
	1	6 volts is too much for 4.5 volts

Question	Score	Sample Answer
7a. These are ordinary torch batteries that have been connected in different ways to a torch globe Circle the pictures where you think the globe will light. Explain why the circuits you chose will light up.	3 2 1	They are joined in a circuit with negative to positive There is an electric current through the battery wire and globe They are joined correctly
7b. Why won't the globes in the other circuits light?	3 2 1	They do not have an electric current passing through them (where previous answer showed knowledge of an electric circuit) They are not connected in a circuit (No knowledge or limited knowledge indicated by previous answer) They aren't joined correctly
8. Here are some more electrical circuits. Circle the one(s) you think will light the globe. Why do you think the circuits will or will not light?	3 2 1	The wood will not because it is a non conductor meaning electrons cannot flow through it while they can flow through metal because metal is a conductor Electricity can't travel through wood but it can travel through metal A will work because a nail is metal B would not work because wood is not metal
9. A battery is connected to a torch globe as shown. The globe is glowing and there is some electrical current flowing through the wires. Put some arrows on the picture to show which direction you think the electrical current is flowing through the wires. Explain why you think the current will flow like that	3 2 1	The electrical current flows from negative to positive in a cycle The battery brings the left over currents in the top and out the bottom Negative goes to positive
10. Here is a series of statements about the amount of current flowing through the wires in the picture for number 9. Circle the one that you think is closest to being right. (a) There is no electric current in wire B. (b) There is some electric current in wire B but less than in wire A. (c) There is the same amount of electric current in wire A as in wire B. (d) There is more electric current in wire B. (e) There is no electric current in wire A. Explain why you chose the answer that you did	3 2 1	The electricity flows evenly in the wire battery and globes If the circuit goes in a circle then the electric current should be the same It goes round in circles
11. Do you think there is any electric current in the battery? Explain why you think that.	3 2 1	In order for the electric circuit to flow in the circuit it has to go through the battery The electric current goes from positive to negative It comes back in the negative side
12. Which of the circuits in this picture would make the light globe glow brightest? Why do you think your choice will be brightest?	3 2 1	No responses scored 3 The electricity travels through the battery and has double the amount of power It's using both the batteries' power
13. Which of the circuits in the picture for question 12 would allow the globe to light for the longer time? Why do you think your choice will last longer?	3 2 1	No responses scored 3 Even though it has two batteries the second battery is there as a sort of backup so it doesn't shine as bright but shines longer The second battery is there to boost the first battery

Extract from Mr Carter's Whole-Class Discussion During Lesson 2 which Involved Conceptual Understandings

Lesson/ Record	Activity	Speaker	Proposition								Speech	Off-task Behaviour				Context
			1	2	3	4	5	6	7	8		G	C	L	H	
Lesson 2																
377	WCD	t						x			Who can tell me a common property of all insulators. All the insulators. What's a common property of the insulators. Probably the wrong way to go around but it might have been easier to ask conductors but bad luck I've asked the question, Peter	T T	T T			Mr Carter standing close to the focus group
378		s						x			They're non metallic		F			
379		t						x			They're non metallic. Therefore, give me a statement, therefore		F F			
380		s						x			Electricity won't flow through them		F			
381		t						x			Electricity won't flow through them. Fair enough.		F F			
382		t						x			What else? Therefore what else? Come on give me a few therefore statements		F F			
383		s						x			Therefore the energy doesn't pass ** Therefore the energy doesn't pass through it.		T F	F		Mr Carter leaves focus group area. Moves around classroom
384		t						x			Therefore the energy doesn't pass through it. Fair enough.	O O	F F	F F		Geoff has chin on arms. does not appear to be listening
385		s	x	x	x			x			Therefore if * put it in a circuit it will break it.	O O	F	F		
386		t	x	x	x			x			If I like this one. Therefore if you put it in a circuit it will break the circuit. Well done, Roger	O O O	F F F	F F F		
388		t						x			It doesn't matter, Allen	O	F			
389		s						x			Therefore there aren't enough electrons in it	O O	F F			
390		t						x			Therefore there aren't enough electrons in insulators. Fair enough		F F			

Extract from Mr Carter's Whole-Class Discussion During Lesson 2 which Involved Conceptual Understandings - cont.

Lesson/ Record	Activity	Speaker	Proposition								Speech	Off-task Behaviour				Context
			1	2	3	4	5	6	7	8		G	C	L	H	
Lesson 2																
391	WCD	t						x			Anything else?	O				
												O				Colin clips an alligator clip to Geoff's finger whilst he has his chin on his arms. Geoff swears Colin is reprimanded
394		t						x			Okay. Well tell me about conductors You've told me about insulators tell me about conductors.	O	T			Geoff chin on arms. Mr Carter asks Colin for an answer. Colin is unable to respond as he has not been listening
397		t						x			Exactly. Tell me about conductors.	O				
398		Colin						x			They make the light glow.	O				
399		t						x			They do indeed but I want to know something that's common about conductors, something that's common. Leigh	O				
												O				
												O				
400		s						x			They all got metal in it.	O				
401		t						x			They contain metal. Mmm. That piece of plastic wire	O				Linda raises hand
												O				
402		s						x			Yeah. I mean like it can only work if you touch the wire.	F	F			
												F	F			
403		t						x			So tell me a bit more about conductors then.	O	F			
404		s						x			Um they only work on uh wire or anything metal.	O	F			
												O	F			
406		t						x			Conductors. No, you you write it. Discuss it in your group. Come up with a sentence that you can come give me that you can write down about conductors. You have to write down somewhere in your page ... Discuss what sentence your group is going to write.	O	F			Students finding worksheets. beginning to talk
												O	F			
												O	F			
												O	F			
												O	F			
												O	F			

Activity - WCD – Whole-class Discussion; Speaker: - t - Mr Carter, s – student; Focus Group: - G - Geoff, C - Colin, L - Linda, H - Helen
Off task behaviour: - W - writing or drawing, U - using equipment, T - talking, F - general fiddling, O - other

Extract from Mr Avery's Focus Group Conceptual Discussions - Lesson 1

Lesson/ Record	Activity	Speaker	Proposition								Speech	Off-task behaviour					Context
			1	2	3	4	5	6	7	8		A	S	J	B	P	
Lesson 1																	
291	GW	Pat				x					Where do you where do you think the electric current would be **		U		W	W	No response from group who are drawing or building circuits
	WCD																Mr Avery calls for attention and asks about current flow
																	Discussed what electric current is
																	Instructions to discuss where the current is in the circuit and the direction of current flow
	GW																Group continued with drawing and building - no discussion
315	WCD	Sue					x				What did we suggest um		T		T	T	Quiet discussion within group at start of whole-class discussion
316		Jon					x				It's it's running from positive to negative		T		T	T	
317		Sue					x				Okay		T		T	T	
319		Pat					x				What		T		T	T	
320		Sue					x				It runs from the positive the negative		T		T	T	
																	Mr Avery's question: "Does anyone know where it (<i>electric current</i>) starts and where it ends?"
325		Bob					x				It ends at the plus						Response to teacher's question
326		Jon					x				No. They run from positive to negative			T			Quiet response to Bob's suggestion
328		Sue					x				I don't think that's right						Response to student's suggestion that current comes from both ends of the battery
329		Unknown					x				No						

Extract from Mr Avery's Focus Group Conceptual Discussions - Lesson 1

Lesson/ Record	Activity	Speaker	Proposition								Speech	Off-task behaviour					Context
Lesson 1			1	2	3	4	5	6	7	8		A	S	J	B	P	
	WCD													U			Discussed connecting points on the globe
														U	U		Instructions to construct circuits using two wires, a battery and a globe. Jon and Bob fiddling.
466	GW	Sue			x						What about if they're both on the positive						Sue and Pat working together, Bob and Jon sometimes working alone and sometimes together. Pairs did not appear to interact with each other. Girls constructed several circuits that got hot
467		Pat			x						Then it gets hot while you're						
469		Sue			x						Oh it gets warm						
470		Sue			x						Try it * won't get hot						
471		Sue			x						It only gets hot if like ones going from the top to the bottom						
472		Pat			x						Yeah, yeah						

Ann was absent for this lesson

Activity: Whole class discussion - Whole-class discussion; Group work - Group work

Focus Group: A - Ann; S - Sue; J - Jon; B - Bob; P - Pat

Off-task behaviour: T - talking, L - listening to group talk, U - using equipment, W - writing or drawing

APPENDIX 8

LIST OF ASSERTIONS

Assertion	Supporting evidence
Assertion 5/1 Approximately half of the interactions in primary science lessons of the type studied relate to management either of the task or of student behaviour.	<u>Related text</u> Chap. 5: Reviews (all teachers)
Assertion 5/2 When the classroom is friendly students are more likely to participate fully in both the discussions and the activities, offering ideas and suggestions and questioning the teacher's statements.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers) Chap. 6: Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a
Assertion 5/3 Students enthusiasm may be increased by the teacher's willingness to listen to and comment on students' successes and ideas either in whole-class or individual settings.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers); Classroom management, (Mr Carter) Chap. 6: Student participation (Mr Avery, Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/4 A variety of methods can be used to provide instructions for activities, some of which are imposed and some which allow students to exercise independence.	<u>Related text</u> Chap. 5: Treatment of current activities (Ms Brown); Chap. 6: General (all teachers); Interaction between teacher and groups (all teachers). Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1.
Assertion 5/5 Less intrusive use of control strategies helps to ensure that lesson flow is maintained.	<u>Related text</u> Chap. 5: Classroom management (all teachers); Whole-class discussion (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Ms Brown's teaching of Proposition 5, Lesson 3
Assertion 5/6 When students are moved to face the teacher during whole-class discussions student attention and participation is improved.	<u>Related text</u> Chap. 5: Types of interactions; Reviews; (Mr Avery); Treatment of current activities; Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/7 When materials are not available during the discussions, student attention and participation is improved.	<u>Related text</u> Chap. 5: Classroom management; Reviews (all teachers) Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/8 Animated whole-class discussion using a variety of strategies helps to maintain student interest and engagement.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers); Treatment of current activities (Mr Avery); Reviews (Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a, Lesson 2, Lesson 3; Mr Avery's teaching of Proposition 3, Lesson 1a, Focus group;
Assertion 5/9 Obtaining responses from many different students helps to maintain student interest.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers); Reviews, Student participation (Mr Avery, Ms Brown) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/10 Questioning a variety of students allows the teacher to become aware of the range of understandings held by the class.	<u>Related text</u> Chap. 5: Treatment of current activities, Student participation (Mr Avery) Chap. 6: Student participation (Mr Avery); Interaction between teacher and groups (Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a
Assertion 5/11 A variety of types of questions elicits a wider range of responses from the students.	<u>Related text</u> Chap. 5: Treatment of current activities (all teachers) Chap. 6: Interaction between teacher and groups (all teachers)
Assertion 5/12 Open questions may be used in many situations to generate ideas and discussion.	<u>Related text</u> Chap. 5: Reviews (all teachers); Treatment of current activities (all teachers) Chap. 6: Interaction between teacher and groups (all teachers)

Assertion	Supporting evidence
Assertion 5/13 The use of a variety of teaching aids and diagrams on the blackboard or from posters, with clear explanations may assist in the development of scientifically acceptable understandings.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers); Reviews (Mr Avery, Mr Carter); Treatment of current activities (Mr Avery) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a, Lesson 1b, Figure 8.1, Changes to students' understanding, Table 9.1; Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/14 Information provided in curriculum materials may not be effectively used.	<u>Related text</u> Chap. 5: Reviews (all teachers); Treatment of current activities (Ms Brown) Chap. 8: Mr Avery's teaching of Proposition 2, All lessons
Assertion 5/15 When parts of a lesson are missed, teachers do not always recognise that they are omitting a part of the curriculum and this will have a negative impact on learning.	<u>Related text</u> Chap. 5: Reviews (all teachers) Chap. 6: General (all teachers) Chap. 8: Mr Avery's teaching of Proposition 2, Lesson 1a, Focus Group
Assertion 5/16 Using analogies helps students to relate abstract ideas to things that they understand and provides opportunities for learning.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Avery); Use of time and interactions during lessons
Assertion 5/17 Some teachers demonstrate little knowledge of students' alternative frameworks.	<u>Related text</u> Chap. 5: Treatment of Current Activities (all teachers) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/18 Teachers may not use scientific terms consistently.	<u>Related text</u> Chap. 5: Teacher and class interactions, Use and understanding of scientific vocabulary and scientific discourse (all teachers) Chap. 8: Mr Avery's teaching of Proposition 2, Lesson 1a, Lesson 1b, Lesson 3
Assertion 5/19 Teachers may not explain all of the scientific terms they use.	<u>Related text</u> Chap. 5: Teacher and class interactions, Use and understanding of scientific vocabulary and scientific discourse (all teachers) Chap. 7: Use and understanding of scientific vocabulary and scientific discourse (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/20 Teachers with a good knowledge of the topic are able to use a wider variety of contexts for developing ideas.	<u>Related text</u> Chap. 5: Treatment of current activities (Mr Avery, Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/21 Teachers with a good knowledge of the topic allow the ideas and activities to be extended by students and are able to comment on and evaluate these.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Avery, Mr Carter); Treatment of current activities (Ms Brown) Chap. 6: Student participation (Mr Avery, Ms Brown); General; Interaction between teacher and groups (Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/22 When students are moved to the front of the class during discussions or demonstrations, student attention and participation is improved.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers); Reviews (Mr Avery) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/23 Where student blackboard drawing is completed when the other students are still working, the students are more likely to pay attention when the drawings are brought to their notice.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Avery); Treatment of current activities, Student participation (Ms Brown) Chap. 7: Focus group work habits (Ms Brown) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1; Lesson 3 Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/24 Where blackboard drawing is accompanied by teacher explanations, the students' attention is better and they have more opportunity to recognise the ideas of other class members.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1, Lesson 3; Mr Avery's teaching of Proposition 3, Lesson 1b

Assertion	Supporting evidence
Assertion 5/25 Where a teacher's understanding of a concept is limited s/he may not recognise students' explanations based on alternative frameworks and may accept or reinforce these.	<u>Related text</u> Chap. 5: Treatment of current activities (Mr Carter) Chap. 6: Interaction between teacher and groups (Ms Brown, Mr Carter)
Assertion 5/26 The teacher's knowledge of the topic affects the quality of his/her explanations.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a Mr Avery's teaching of Proposition 3, Lesson 1b
Assertion 5/27 Clear and accurate explanations from the teacher give the students the opportunity to develop scientifically acceptable understandings.	<u>Related text</u> Chap. 5: Treatment of current activities (all teachers) Chap. 6: Interaction between teacher and groups (Mr Avery, Ms Brown) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a, Lesson 1b, Remaining Lessons; Figure 8.1, Changes in understanding, Table 8.1; Ms Brown's teaching of Proposition 5, Lesson 1a, Lesson 2, Lesson 3, Figure 8.2, Changes in understanding, Tables 8.2, 8.3 Mr Avery's teaching of Proposition 3, Lesson 1a; Mr Avery's teaching of Proposition 2, Lesson 1a, Lesson 1b;
Assertion 5/28 The tone of a teacher's voice may cue the students to the correct response.	<u>Related text</u> Chap. 5: Treatment of current activities (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a
Assertion 5/29 The correct answer needs to be identified when a variety of responses are accepted for an open question.	<u>Related text</u> Chap. 5: Treatment of current activities (all teachers) Chap. 6: Interaction between teacher and groups (all teachers) Chap. 9: Mr Avery's teaching of Proposition 5, Lesson 1a; Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 5/30 The generation of a variety of ideas leads students to recognise and question other's ideas.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Avery, Ms Brown) Teacher and class interactions (all teachers); Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Ms Brown's teaching of Proposition 5, Lesson 1; Mr Avery's teaching of Proposition 3, Lesson 1a, Focus Group
Assertion 5/31 Regular reviews give students who have been absent for one or more lessons an opportunity to find out what has been covered.	<u>Related text</u> Chap. 5: Reviews (all teachers) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 2
Assertion 5/32 Students have more opportunities to construct understandings when time is allowed for regular, effective reviews of work to be conducted.	<u>Related text</u> Chap. 5: Figures 5.1, 5.2, 5.3, 5.4, 5.5, 5.6; Types of interactions during whole-class discussion – Reviews (all teachers) Chap. 6: Interaction between teacher and groups (Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 5, All lessons, Figure 8.1, Table 8.1; Ms Brown's teaching of Proposition 5, Lesson 2, Lesson 3, Figure 8.2, Comparison of teaching, Table 8.3; Mr Avery's teaching of Proposition 3, All lessons, Figure 8.8, Changes in understandings, Table 8.4
Assertion 5/33 Reviews directed by the teacher are likely to be more comprehensive than those where student responses guide the discussion.	<u>Related text</u> Chap. 5: Reviews (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a
Assertion 5/34 Where links are not clearly made between parts of a lesson and/or individual lessons, students may have more difficulty constructing understandings.	<u>Related text</u> Chap. 5: Reviews (all teachers) Chap. 6: Interaction between teacher and groups (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a, Figure 8.1, Changes in understandings, Table 8.1 Mr Avery's teaching of Proposition 3, Lesson 1a, Remaining lessons, Figure 8.8, Changes in understandings, Table 8.4

Assertion	Supporting evidence
Assertion 5/35 The students' involvement in the construction of explanations during discussions helps to maintain interest and allows them more opportunities to develop understandings.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Avery, Ms Brown); Teacher and class interactions (all teachers); Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Ms Brown's teaching of Proposition 5, Lesson 1; Mr Avery's teaching of Proposition 3, Lesson 1a, Focus Group
Assertion 5/36 When students are interested and involved in the discussion and activities they are more likely to ask questions and offer suggestions.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers) Chap. 6: Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a; Ms Brown's teaching of Proposition 5, Lesson 1a, Lesson 3
Assertion 5/37 The students' ability to extend or justify their answers allows more complete answers to be generated and gives teachers more opportunity to recognise understandings.	<u>Related text</u> Chap. 5: Whole-class discussion (Mr Carter); Treatment of current activities (Mr Carter); Types of interactions-Reviews-Student participation (Mr Avery); Student participation (Mr Avery, Ms Brown) Chap. 6: Interaction between teacher and groups (Mr Avery, Mr Carter); Student participation (all teachers) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/38 Where explanations or student answers are fragmented it is more difficult for other students to construct understandings.	<u>Related text</u> Chap. 5: Reviews, Student participation (Ms Brown) Treatment of current activities (Mr Carter) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/39 Where teachers need to use many questions to help students respond, the fragmented answers need to be summarised to clarify the explanation.	<u>Related text</u> Chap. 5: Reviews- Student participation (Ms Brown) Chap. 6: Interaction between teacher and groups (Mr Carter) Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 5/40 When students are involved in meaningful demonstrations they and the rest of the class are more attentive.	<u>Related text</u> Chap. 5: Whole-class discussion (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a;
Assertion 5/41 When students are involved in evaluating and correcting blackboard diagrams, there are more opportunities for the development of scientifically acceptable understandings.	<u>Related text</u> Chap. 5: Treatment of current activities (Mr Avery) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a, Fig. 8.1, Changes in understanding, Table 8.2; Mr Avery's teaching of Proposition 3, Lesson 1a, Lesson 1b, Focus group, Fig 8.8. Changes in understanding, Table 8.4
Assertion 5/42 Students are unlikely to use many new scientific terms in their discussions.	<u>Related text</u> Chap. 5: Use and understanding of scientific vocabulary and scientific discourse. Student use of scientific vocabulary (all teachers) Chap. 6: Use of scientific language (all teachers) Chap. 7: Use and understanding of scientific vocabulary and scientific discourse (all teachers)
Assertion 6/43 During teacher visits to groups, the number of interactions from the teacher and the students are usually similar in quantity although teacher utterances are generally longer.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers)
Assertion 6/44 Where student interactions are higher than that of the teacher, the teacher has more opportunity to recognise students' understandings.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers)

Assertion	Supporting evidence
Assertion 6/45 In most classes during group work, the number of utterances from teachers or students that relate to management, either of the task or of student behaviour, is higher than those related to developing understandings.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers)
Assertion 6/46 Curriculum materials may be manipulated to support a teacher's style of teaching but still maintain the integrity of the materials.	<u>Related text</u> Chap. 6: General (Mr Carter)
Assertion 6/47 A quick initial check of all groups ensures students understand the task and have the correct materials.	<u>Related text</u> Chap. 6: General (all teachers) Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a;
Assertion 6/48 Student involvement in activities is increased when students are able to progress at their own rate and they become bored and off-task when they are required to wait for instructions from the teacher.	<u>Related text</u> Chap. 6: Student participation (all teachers) Chap. 7: Focus Group (Mr Avery, Ms Brown); Focus Group work habits (Mr Avery)
Assertion 6/49 Because of the demands of supervising group work in a given class, teachers may miss visiting some groups which may disadvantage those groups.	<u>Related text</u> Chap. 6: General (all teachers). Chap. 8: Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 6/50 Listening to group discussion or reading student notes enables the teacher to ascertain student understandings and pose questions to facilitate the development of ideas and understandings of students in that group.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers) Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a
Assertion 6/51 Teacher visits to groups may be used to facilitate the development of conceptual understandings through discussion and questioning.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers). Chap. 7: Types of interactions (Mr Avery) Chap. 8: Ms Brown's Teaching of Proposition 5, Lesson 1
Assertion 6/52 Acceptance in the group discussion of students' answers that are based on unscientific beliefs may result in students retaining incorrect understandings if the concept is not later discussed and clarified in the whole-class discussion.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers) Chap. 7: Interactions within the Focus Group (Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 2, Lesson 1a. Focus Group
Assertion 6/53 Information and ideas developed with or given to individual groups also need to be given to the whole-class.	<u>Related text</u> Chap. 6: General (all teachers); Interaction between teacher and groups (all teachers) Chap. 8: Ms Brown's teaching, Lesson 1
Assertion 6/54 Visits to groups may be used to review previous work or understandings and make links to current understandings.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers)
Assertion 6/55 Teachers find different ways of helping students with practical tasks, some of which may allow the students more opportunity to learn than others.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers). Chap. 8: Mr Avery's teaching of Proposition 3, Lesson 1a, 1b.
Assertion 6/56 Students need to be taught how to work collaboratively and to solve problems within a group situation.	<u>Related text</u> Chap. 6: Interaction between teacher and groups (all teachers); General (Ms Brown) Chap. 7: Focus Group (all teachers); Types of interactions (all teachers); Focus group use of group work time (Mr Carter) Focus Group work habits (Mr Carter)

Assertion	Supporting evidence
Assertion 6/57 Turn-taking and cooperation in groups may be maintained by low key management or strong management solutions. However, imposed management solutions may only work for a limited time.	<u>Related text</u> Chap. 6 Interaction between teacher and groups (Mr Avery, Mr Carter); General (Ms Brown)
Assertion 6/58 Students may use teacher visits to their group to check their understandings and/or that they are working correctly on the assigned practical task.	<u>Related text</u> Chap. 6 Student participation (all teachers) Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a
Assertion 7/59 Students with a greater knowledge of the topic than other group members may offer their information or ideas in a helpful or dictatorial manner which may affect the development of understanding.	<u>Related text</u> Chap. 7: Interactions within the Focus Group (Mr Carter); Types of interactions (Mr Avery, Ms Brown) Chap. 8: Mr Avery's Teaching of Proposition 5, Focus group
Assertion 7/60 The choice of students to work together in groups needs to be planned carefully to avoid dysfunctional groups	<u>Related text</u> Chap. 7: Focus Group (all teachers) Focus group use of group work time (Mr Carter)
Assertion 7/61 A student may direct the group in an unobtrusive manner but still have the role of leader.	<u>Related text</u> Chap. 7: Focus Group (Ms Brown)
Assertion 7/62 The presence of a leader in a group, even if this role is rotated between students, facilitates group work.	<u>Related text</u> Chap. 7 The Focus Group (all teachers) Chap. 8: Mr Avery's Teaching of Proposition 5, Focus group; Mr Avery's teaching of Proposition 3, Focus Group
Assertion 7/63 Individual group members, either male or female, may use the equipment to the exclusion or partial exclusion of others.	<u>Related text</u> Chap. 7: Focus Group (Ms Brown); Focus Group work habits (Ms Brown)
Assertion 7/64 Students with less knowledge in a mixed ability group may not participate as effectively in activities and discussions as those with more knowledge.	<u>Related text</u> Chap. 7 The Focus Group (all teachers); Focus group use of group work time (Mr Avery); Interactions within the Focus Group (Mr Avery, Ms Brown) Chap. 8: Mr Avery's teaching of Proposition 3, Focus group
Assertion 7/65 Students in groups need to ensure that all members are involved in the task.	<u>Related text</u> Chap. 7: Types of interactions (all teachers)
Assertion 7/66 The students' level of attention during group work may affect their opportunities to learn.	<u>Related text</u> Chap. 7: Focus group use of group work time (all teachers)
Assertion 7/67 The attendance of a teacher at a group improves group attentiveness.	<u>Related text</u> Chap. 7: Focus Group (Mr Carter)
Assertion 7/68 Groups need to be taught strategies to enhance attentiveness.	<u>Related text</u> Chap. 7: Focus Group work habits (Ms Brown, Mr Carter); Focus Group (Mr Carter)
Assertion 7/69 The social dynamics of the group may affect their on-task behaviours.	<u>Related text</u> Chap. 7: Focus group use of group work time (all teachers)
Assertion 7/70 Groups which infrequently engage in extended social conversation demonstrate more success in completing tasks.	<u>Related text</u> Chap. 7: Focus group work habits (all teachers)
Assertion 7/71 Groups which engage in positive interactions demonstrate more success in completing tasks.	<u>Related text</u> Chap. 7: Focus group use of group work time (all teachers); Types of interactions (Mr Avery, Ms Brown)

Assertion	Supporting evidence
Assertion 7/72 Students who do not complete practical activities may find it more difficult to develop understandings.	<u>Related text</u> Chap. 7: Focus group use of group work time (Ms Brown)
Assertion 7/73 Friendly interactions and effective discussion skills provide more opportunities for learning and therefore better construction of understandings.	<u>Related text</u> Chap. 7: Types of interactions (all teachers)
Assertion 7/74 Students who engage in cooperative discussion give all students in the group opportunities to develop understandings.	<u>Related text</u> Chap. 7: Types of interactions (all teachers)
Assertion 7/75 Answers which include explanations allow more opportunity for discussion and learning.	<u>Related text</u> Chap. 7: Types of interactions (Mr Avery); Interactions within the Focus Group (Ms Brown) Chap. 8: Mr Avery's teaching of Proposition 3, Focus Group
Assertion 7/76 Students who are able to accept and build on comments from others have more opportunities to develop understandings.	<u>Related text</u> Chap. 7 Focus group use of group work time (Mr Avery); Types of interactions (all teachers) Chap. 8: Mr Avery's teaching of Proposition 3, Focus Group
Assertion 7/77 Students who engage in incidental discussion during activities as well as the discussions suggested by the teacher, have more opportunities to develop understandings.	<u>Related text</u> Chap. 7 The Focus Group (all teachers); Types of interactions (Mr Avery, Ms Brown)
Assertion 7/78 Group discussion in primary schools is often only made up of short statements.	<u>Related text</u> Chap. 7: Focus group use of group work time (all teachers)
Assertion 7/79 Teacher support enables more constructive discussions to occur.	<u>Related text</u> Chap. 7: Focus Group (Mr Carter); Focus group use of group work time (Mr Avery)
Assertion 7/80 Students who are used to working independently of the teacher maintain this when working in groups.	<u>Related text</u> Chap. 7 The Focus Group (all teachers)
Assertion 7/81 A framework for discussion, e.g. a list of questions which need responses, encourages all the students to respond in a discussion. However, it may not necessarily result in good discussion.	<u>Related text</u> Chap. 7: Focus Group (Mr Avery, Mr Carter) Chap. 8: Mr Avery's teaching of Proposition 3, Focus Group
Assertion 7/82 Even when students appear inattentive during whole-class discussions they may still be paying attention.	<u>Related text</u> Chap. 7: Focus Group work habits (Mr Avery)
Assertion 8/83 Teachers who are less aware of alternative frameworks may, by restricting discussion either in group work or in whole-class discussion, not give students the opportunity to recognise and discuss other ideas.	<u>Related text</u> Chap. 8: Mr Avery's teaching of Proposition 5, Lesson 1a Ms Brown's teaching of Proposition 5, Lesson 1
Assertion 8/84 Even when information is not presented clearly and effectively by the teacher in the whole-class discussion, students may still improve their understanding of a concept. This may be through whole-class interactions or from interactions with other group members.	<u>Related text</u> Chap. 8: Ms Brown's teaching of Proposition 5, Changes in students understandings, Table 8.2; Mr Avery's teaching of Proposition 2, Changes in students understandings

Assertion	Supporting evidence
Assertion 8/85 Sufficient time needs to be allowed in all lessons for the students to engage in discussion and reflection.	<u>Related text</u> Chap. 8: Mr Avery's teaching of Proposition 2, Lesson 1a, Focus Group
Assertion 9/86 Where teachers are knowledgeable and use a wide variety of methods to illustrate and explain phenomena, with students engaged in discussion and constructing ideas, the students have more opportunities for learning and are more likely to reach scientifically acceptable understandings.	<u>Related text</u> Chap. 9: Mr Avery and Mr Carter, Comparison of Classes
Assertion 9/87 Where teachers omit parts of the curriculum or do not use the supplied materials, students may not be given the opportunity to develop scientifically acceptable understandings.	<u>Related text</u> Chap. 9: Mr Avery, Proposition 2; Ms Brown, all Propositions; Mr Carter, Proposition 8
Assertion 9/88 Where effective reviews are not conducted it is likely that any improvement in understanding will be limited.	<u>Related text</u> Chap 9: Ms Brown, all propositions; Mr Carter Propositions 7 and 8
Assertion 9/89 Groups that do not have the skills to work cooperatively are less likely to improve their understanding of the concepts under investigation.	<u>Related text</u> Chap. 9: Comparison of Classes, Focus Groups, all classes
Assertion 9/90 Students who do not appear to be overtly participating effectively in the group activities may still substantially improve their understanding of the concepts under investigation.	<u>Related text</u> Chap. 9: Comparison of Classes, Focus Groups, all classes
Assertion 9/91 Dramatic or interesting methods of illustrating phenomena result in more learning taking place.	<u>Related text</u> Chap. 9: Mr Avery, all propositions except Proposition 6; Ms Brown, all proposition; Mr Carter, Proposition 1
Assertion 9/92 Where teachers have non-scientific understandings these are hard to change and may be passed on to the students.	<u>Related text</u> Chap. 9 Mr Carter, Proposition 5